April 28 - 29, 2010 ■ Disaster City, TX

Near-Collapse Buildings Workshop

for Emergency Management Personnel

Homeland Security

Science and Technology

Texas Engineering Extension Service

Because science and technology are crucial to mitigating natural and manmade effects on critical infrastructure and ensuring the continuity of their services, the U.S. Department of Homeland Security (DHS) Science and Technology (S&T) Directorate has established a goal to accelerate the delivery and understanding of enhanced technological capabilities. In support of this goal, the Infrastructure and Geophysical Division (IGD) of the Science and Technology Directorate, U.S. Department of Homeland Security established a program to investigate the enhancement of building stabilization after an improvised explosive device (IED) attack. To that end, DHS S&T sponsored the 2010 Near-Collapse Buildings Workshop for Emergency Management Personnel.

Through white paper discussions and breakaway sessions, participants in the workshop investigated the on-site needs and concerns of emergency management personnel (firefighters, search and rescue, police, and emergency medical personnel). The decisions of emergency management personnel and rescue engineers on site are critical to the stabilization of a building susceptible to collapse.

The results of this workshop will help facilitate research and development of state-of-the-art technologies and methods to stabilize structures after an IED attack. These efforts are anticipated to lead to a technology transfer to the private sector, which will allow the rapid deployment of products to stabilize buildings after they have been impacted by IEDs.

The Infrastructure and Geophysical Division of the U.S. Department of Homeland Security's Science and Technology Directorate would like to thank the Texas Engineering Extension Service (TEEX) for hosting the conference and providing space and support.

Christopher Doyle
Director
Infrastructure Geophysical Division
Science & Technology Directorate
U.S. Department of Homeland Security

Ruth M. Doherty, Ph.D.
Program Executive Officer
PEO (C-IED)
U.S. Department of Homeland Security

ACKNOWLEDGEMENTS

Many abstracts were submitted to the workshop committee for consideration in response to the call for abstracts. All abstracts were reviewed by two independent reviewers. Some of the review considerations were originality, completeness, and suitability to the workshop goals. IGD acknowledges the efforts of the reviewers in this process. They provided expert technical opinions in a timely manner. Their efforts helped to ensure high quality presentations and achievement of this workshop's desired goals.

IGD would also like to express thanks to the workshop committee for their diligent efforts in organizing and successfully carrying out this workshop. The committee is:

- Mila Kennett, Program Manager, DHS/S&T/IGD
- Tom Coleman, DHS/S&T/IGD
- Eric Letvin, Project Manager and Facilitator, URS
- Mohammed Ettouney, Senior Technical Advisor and Coordinator, Weidlinger
- Holly Stone, Senior Technical Advisor and Coordinator, Stone Security Engineering
- Gwendolyn Hall, Senior Advisor and Logistic Coordinator, URS
- Fernando Cortez-Lira, Systems Engineering and Technical Assistance Support, Analytical Research LLC
- Robert Hall, Engineering Innovations, LLC
- Tate Jackson, Senior Engineer and Workshop Support, URS
- RJ Walker, Workshop Support, URS
- Laura Seitz, Workshop Support, URS

IGD would also like to thank our hosts at TEEX and Texas A&M for their support in organizing this workshop. The host committee is:

- Bob McKee, Director, TEEX/US&R
- Jeff Bolich, Program Director, TEEX/US&R
- Peter Keating, Associate Professor, Texas A&M University

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Day 1 – Wednesday, April 28, 2010

9:00 Welcome and Announcements

Milagros Kennett – DHS, S&T / IGD
Chief Bob McKee – Director, TEEX/US&R

9:15 ***Session 1*** Problem Definitions

Keynote: *Don Roy and Chris Gallagher*
Building Stabilization: A First Responder Perspective

Eric Letvin and Mohammed Ettouney
Overview of Stabilizations of Buildings Project and Goals of Workshop

K.C. Mahboub
Rapidly Deployable System for the Structural Stabilization of Shock Damaged Structures

Jon Rigolo
Evolution of Response to an Emergency

Dean Tills
Goals and Demands of Operations in Near-Collapse Buildings: Case Studies from Disasters over the Past 15 Years

Scott Nacheman
Collapse Case Study and Technology Transfer Opportunities

11:30 *Break*

11:45 ***Session 2*** Physical Behavior of Collapsing Buildings: Modeling, Debris, and Mitigation Measures

John O'Connell
Emergency Rescue Shoring Concepts

David Hammond
Destructive Testing of Near-Collapse Mitigation Measures: Wood Shoring, Metal Adjustable Struts, Steel Jackets, and Expansion Anchors

12:30 *Lunch*

1:30 PM **_Session 2_** Continued

Shalva Marjanishvili
Fire-Induced Collapse of Damaged Structures

Hollice Stone for Arturo Montalva
An Approach to Correlating Air-Blast Analysis Results and Post-IED Structural Residual Capacity

2:30 **_Session 3_** Decision Thresholds and Risk Management

Brian Beadnell
A Possible Approach to Developing IED Rapid Response Support Packages

Peter Keating
The Need for Research into Brittle Failure Modes and Subsequent Possibilities for Real-Time Monitoring during Rescue Operations – A Case Study

Bil Hawkins
When Rescue Turns to Recovery

Mohammed Ettouney
Risk-Based Rapid Visual Screening Tools for Near-Collapse Buildings

4:30 **_Breakaway Session: Working Groups_**
1A: Physicality of Collapsing Buildings
2B: Thresholds and Risk Management

6:00 **_Adjourn for the day_**

Day 2 – Thursday, April 29, 2010

7:45 Reporting of Day 1 Sessions and Resolutions
Introductions to Day 2

8:00 ***Session 4*** Emerging Technologies

Earle Kennett
BIM Basics and Utilization for Building Stabilization Efforts

Ahmed Al-Ostaz
Current Technologies in Materials and Rapidly Deployable Shoring, Stabilizing and Piping Equipments for Building Stabilization after IED Attacks

David Mascarenas
The Development of Mobile Host Wireless Sensor Networks for Rapid Structural Assessments

Robin Murphy
Use of Small Unmanned Ground and Aerial Vehicles for Structural Assessment and Reach-Back

Hollice Stone
How New and Evolving Building Technologies Can Affect First Responders' Operations

Zach Smith
Fast-Setting FRP Composite Systems to Structurally Retrofit and Stabilize Reinforced Concrete Columns for Post-Extreme Loading

Thomas Attard
Development of a New Lightweight 'Rubberized-Carbon' Composite for New or Already-Damaged Structures

10:45 ***Breakaway Session: Working Groups***
Group 2A: Emerging Technologies
Group 2B: Testing Needs

11:45 ***General Assembly and Resolutions***

12:15 Lunch

1:00 PM ***Tour of Disaster City***

5:00 ***Tour Ending***

SESSION 1
PROBLEM DEFINITIONS

Don Roy

Chief Donald Roy recently retired in June 2009 after serving with Los Angeles County Fire Department for over 30 years. For approximately 7 years Chief Roy has worked as a TEEX Adjunct Instructor. While working as an adjunct he provided assistance in developing and writing material for the Logistics Specialists course. He has also participated in multiple focus groups as a Subject Matter Expert.

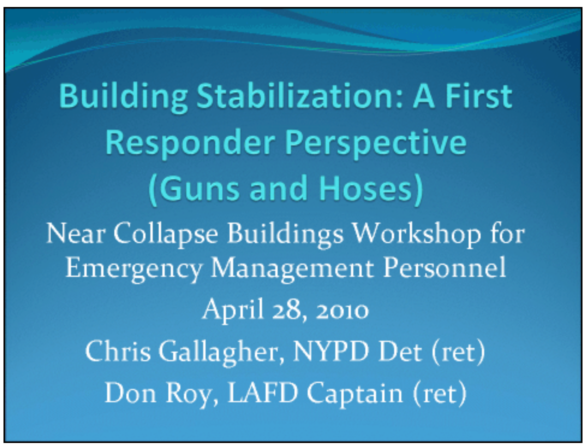
Chris Gallagher

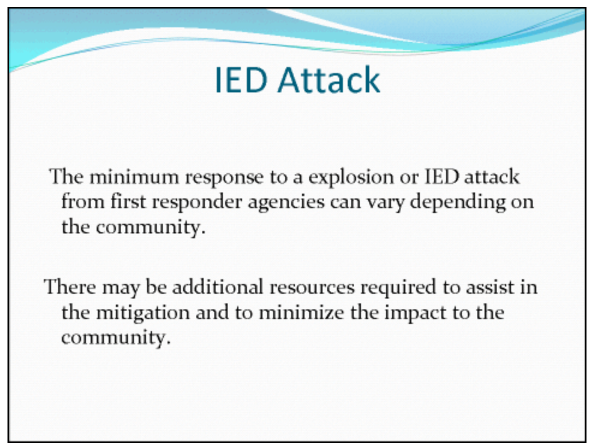
Chris Gallagher has been a Logistics Specialist for the FEMA New York Task Force 1 since 1997. Mr. Gallagher has been involved in emergency management for 30 years. He spent 14 years in the U.S. Marine Corps, 19 years as a volunteer firefighter, 16 years as a New York City Police Officer, and 5 years in the New York City Office of Emergency Management. Mr. Gallagher was deployed to the World Trade Center after the September 11 attacks.

Keynote – Building Stabilization: A First Responder Perspective

The keynote presentation is a discussion of Mr. Roy and Mr. Gallagher's experiences with near-collapse buildings from the perspective of the first responder.

Presentation Slides





Decision Making

- Fire/ EMS-
  - Secure area and to provide aid to ambulatory
  - Set up MCI
  - Heavy Rescue Operations


Decision Making

- Police-
  - Secure Area and evacuate using ATF explosive standards
  - Check for additional devices and mitigate as necessary


Vehicle born IED Standards

BATF Explosive Standards

ATF	Vehicle Description	Maximum Explosives Capacity	Lethal Air Blast Range	Minimum Evacuation Distance	Falling Glass Hazard
	Compact Sedan	500 pounds 227 Kilos (In Trunk)	100 Feet 30 Meters	1,500 Feet 457 Meters	1,250 Feet 381 Meters
	Full Size Sedan	1,000 Pounds 455 Kilos (In Trunk)	125 Feet 38 Meters	1,750 Feet 534 Meters	1,750 Feet 534 Meters
	Passenger Van or Cargo Van	4,000 Pounds 1,818 Kilos	200 Feet 61 Meters	2,750 Feet 838 Meters	2,750 Feet 838 Meters
	Small Box Van (14 Ft. box)	10,000 Pounds 4,545 Kilos	300 Feet 91 Meters	3,750 Feet 1,143 Meters	3,750 Feet 1,143 Meters
	Box Van or Water/Fuel Truck	30,000 Pounds 13,636 Kilos	450 Feet 137 Meters	6,500 Feet 1,982 Meters	6,500 Feet 1,982 Meters
	Semi-Trailer	60,000 Pounds 27,273 Kilos	600 Feet 183 Meters	7,000 Feet 2,134 Meters	7,000 Feet 2,134 Meters

Different Structures

- The different type of structures vary depending on the geographical area.
- The structural integrity can be compromised.

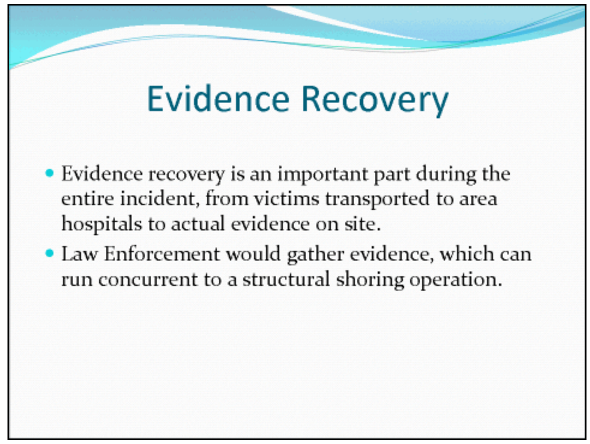
  Above grade

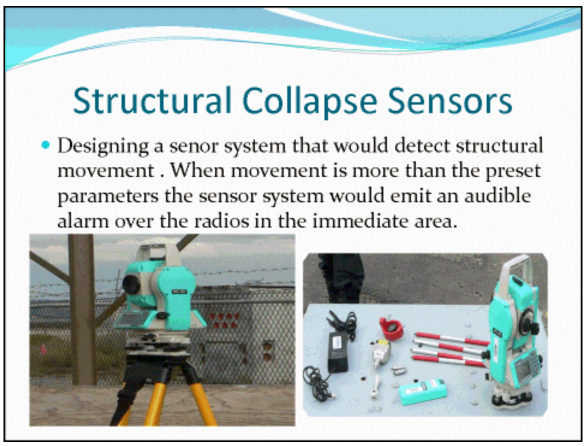
  Below Grade

  Floating

Above Grade Structures

Below Grade Structures





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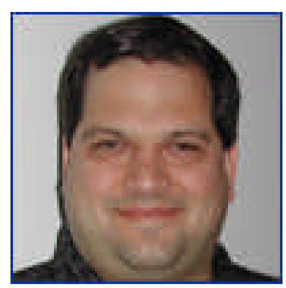
Eric Letvin



Eric Letvin, PE, Esq., is a Principal Engineer and Attorney for the URS Corporation in Linthicum, Maryland. He has more than 15 years of experience in multi-hazard mitigation and design, serving Federal, State, and local clients. He has experience in infrastructure risk assessments, post-disaster forensic analysis, hazard/threat identification, vulnerability assessments, and the design of protective measures for man-made threats and natural hazards. He served as project manager of the FEMA/ASCE team that performed the engineering study of the World Trade Center disaster, and has participated in numerous post-disaster studies including the bombing of the Murrah Building in Oklahoma City, Hurricanes Opal, Ike, and Katrina. He has assessed over 200 buildings for risk from terrorist threats and natural disasters.

Mr. Letvin is part of the subject matter expert team working on the development of the rapid visual screening tool with FEMA, DHS' Science & Technology Directorate. He is the program manager for URS's contract with DHS' Protection and Programs Directorate (Office of Infrastructure Protection). He regularly teaches courses in building design in disaster-resistant construction for FEMA throughout hurricane-prone regions of the United States. He has taught FEMA's Building Design for Homeland Security Course, which teaches students how to conduct risk assessments of critical infrastructure and design protective measures, 23 times to over 400 people in the past 5 years.

Mr. Letvin has been the consultant project manager for numerous FEMA mitigation publications, including the recently released FEMA 453, Design Guidance for Shelters to Protect Against Terrorist Attacks; FEMA 426, Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings; FEMA 452, Risk Assessment: A How-To Guide to Mitigate Potential Terrorist Attacks; and FEMA 428, Primer to Design Safe School Projects Against Terrorist Attacks.

Mr. Letvin holds bachelor's and master's degrees in civil engineering from Syracuse University and received his Juris Doctor from the University of Maryland.

Mohammed Ettouney

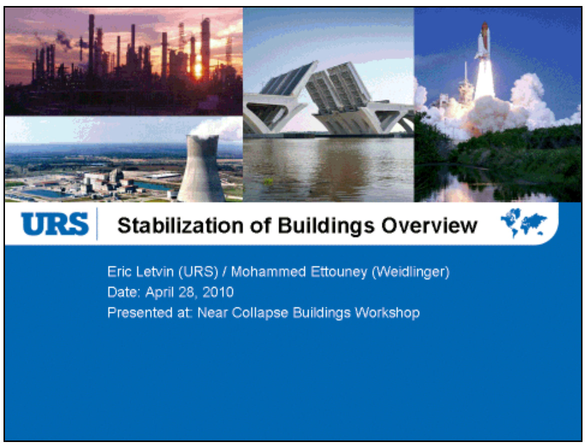
Mohammed M. Ettouney, Ph.D., P.E., F. AEI is a Principal at Weidlinger Associates, Inc. The Inventors Hall of Fame recently awarded Dr. Mohammed Ettouney the inventors' award, after he was nominated to receive such a great honor by the American Society of Civil Engineers (ASCE). He was also awarded the Homer Gage Balcom life achievement award by the MET section of ASCE (2008). He also has just won the Project of the Year Award, Platinum Award (2008) for the "New Haven Coliseum Demolition Project" (ACEC, NY). He is a fellow of Architecture Engineering Institute (AEI). Among other recent achievements are the pioneering work on "Theory of Multi-hazards of Infrastructures," "Theory of Progressive Collapse" (DoD), risk Model for Building Security Council (BSC) rating system and innovative green design method for protecting utilities from demolition / blasting (City of New Haven). He has professional interest in diverse areas of structural engineering as demonstrated through the list of his publications, invited presentations, seminars and sessions organized during national/international conferences and his membership in different professional organizations.

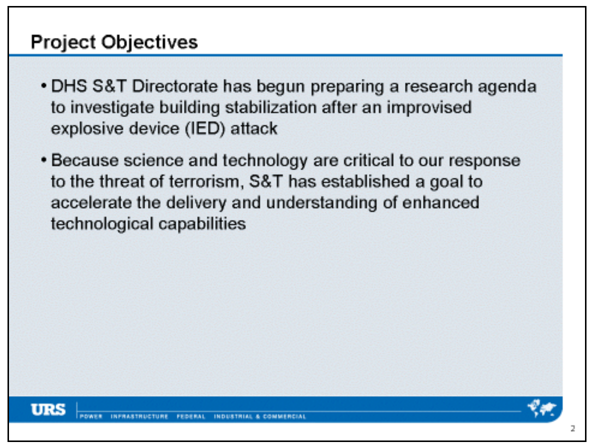
Dr. Ettouney has been with Weidlinger Associates since 1984. He received his Doctor of Science degree in Structural Mechanics from the Massachusetts Institute of Technology (MIT), Cambridge, MA, in 1976. Since then, his interests in the structural engineering profession were both as a practitioner and researcher in multi-hazards safety of structures, probabilistic Modeling of Progressive Collapse of Buildings and uncertainties in structural stability, and blast mitigation of numerous buildings around the world; innovative concepts such as "Probabilistic Boundary Element Method," "Scale Independent Elements," and "Framework for evaluation of Lunar Base Structural Concepts". He is a past president and member of board of governs of AEI, member of Board of Directors of the BSC, member of numerous technical committees in the fields of building/infrastructures security, earthquake hazards, architectural engineering Non-Destructive Testing and Structural Health Monitoring. He was the chair of AEI National Conference, 2006, and 2008. He has published more than 325 publications and reports, and has contributed to several books. He introduced numerous new practical and theoretical methods in the fields of earthquake engineering, acoustics, structural health monitoring, progressive collapse, blast engineering, and underwater vibrations. He has co-invented "Seismic-Blast" slotted connection. More recently, he introduced "Economic Theory of Inspection," "General and Special Theories of Instrumentation" and numerous principles and techniques in the field of infrastructures health: they are all pioneering efforts that can help in developing durable infrastructures at reasonable costs. He is coauthoring an upcoming book titled, "*Infrastructures Health in Civil Engineering*," CRC Press, 2009. The book is already being described as a breakthrough and original in the field of infrastructure health and preservation.

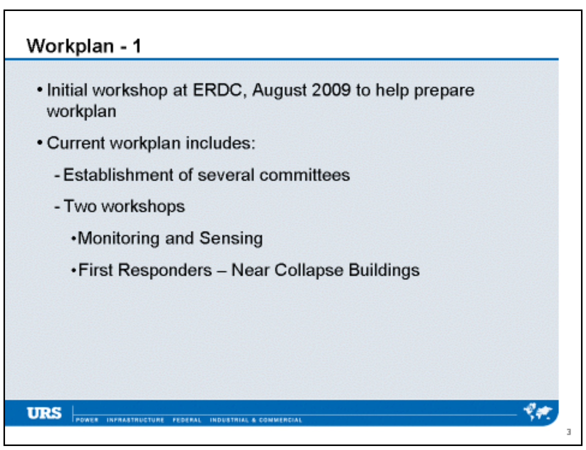
Overview of Stabilizations of Buildings Project and Goals of Workshop

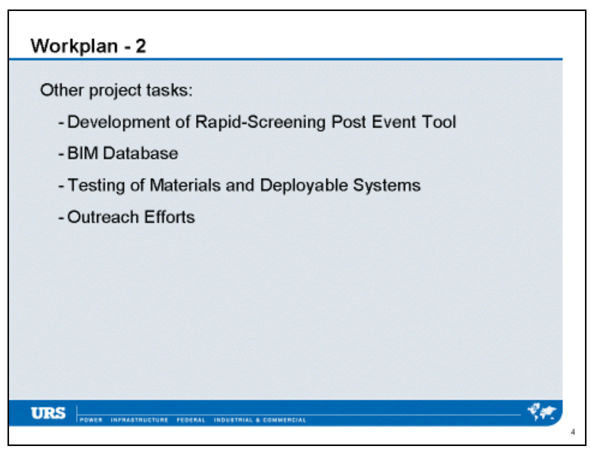
Eric Letvin and Mohammed Ettouney presented an overview of the Stabilizations of Buildings project including major tasks and the committee structure. A brief description and review of the workshop is discussed.

Presentation Slides









Committees

Oversight of Entire Project (Review Committee):

- U of Mississippi, ERDC, FEMA US&R (Holly Stone)
- Dr. Robert Hall
- Dr. Mohammed Ettouney
- Tate Jackson - coordination

Workshop at ERDC August - 2009

- Held initial Stabilization of Buildings after an IED Attack workshop in August 2009 at the US Army Corps Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi
- The agenda identified:
  - A list of research priorities and information gaps
  - Information through current data and literature
  - Potential tools, materials, and systems leading to the stabilization of buildings
  - Areas of collaboration and funding sources
  - Sector involvement and commercialization

Monitoring and Sensing Workshop Objectives

- State of the art and knowledge gaps in monitoring and sensing technologies
- Information needed by emergency management personnel

Monitoring and Sensing Workshop Objectives: 3

- Monitoring and sensing technologies that need to be developed to better process information
  - Ways to identify type of data that needs to be monitored and conveyed
  - Damage identification methods of near-collapse buildings
  - Structural identification/analysis methods of near-collapse buildings
- Pre-event versus post-event sensors (deployed by emergency management personnel and the Federal Emergency Management Agency [FEMA] Urban Search & Rescue [US&R] personnel)

First Responders Workshop College Station, TX, April 2010: Objectives

- To investigate the on-site needs and concerns of emergency management personnel
- Obtain a clear understanding of emergency management personnel needs will help facilitate research and development of state-of-the-art technologies and methods to stabilize structures after an IED attack
- State-of-the-art building stabilization technologies for emergency management personnel (e.g., shoring, sensing, monitoring, victim/void identification technologies)

First Responders Workshop Objectives: 2

- Knowledge gaps and future needs in building stabilization technologies
- Current research into building stabilization technologies
- Real-time, on-site coordination and information sharing between engineers and emergency management personnel
- How new and evolving building construction technologies affect future search and rescue activities

Committees

- 4 Committees
  - Monitoring, Sensing and Modeling
  - Risk Assessment and Decision-Making
  - Building Stabilization Technologies and Testing
  - Building Information Management (BIM)
- 2-4 persons on each committee
- Committee will propose research / technologies for funding
- Committee membership time is funded

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Committee – Monitoring, Sensing, and Modeling

- Research the state-of-the-art and knowledge gaps in monitoring and sensing technologies and modes of failure. Determine the information needed by first responder personnel, and identify technologies for research, modeling, and testing.
- 5 potential individuals expressed interest after workshop in early April

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Committee – BIM

- Work to create BIM model/module that can be adopted by industry and used by the first responder community to assist with disaster response for an IED

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Committee – Risk Assessment and Decision-making

- The development of post-disaster tools and guidelines that facilitate the risk assessment and decision making process for first responders
  - Prepare a simplified tool and/or guidelines to determine risk for collapsed or near collapse structures that have been subjected to an IED attack. The tool could take the form of a checklist and will include pertinent building components.
  - Create decision making tools that can be used by responders (local fire departments and FEMA US&R responders) for the translation of data resulting from monitoring systems

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Committee – Building Stabilization Technologies and Testing

- Research and test innovative stabilization techniques for different building types after an IED attack. These test simulations will include testing protocols that will be approved by DHS prior to their delivery.

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Outreach Efforts

- Provide the mechanisms for disseminating information on stabilizing buildings after IED attacks into public and private sectors
- Disseminate materials and technologies that demonstrate effectiveness at stabilizing buildings

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K.C. Mahboub

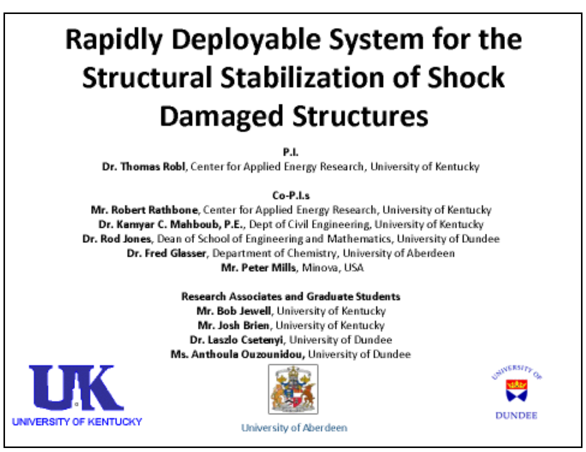
Dr. K. C. Mahboub, P.E., has made a significant contribution to the field of civil engineering through his many years of teaching, research, service, and consulting. His original work in the area of mechanistic characterization of construction materials has been published in peer-reviewed journals. Dr. Mahboub is a firm believer in technology transfer. For example, as a part of his research, Dr. Mahboub worked very closely with the construction industry and Kentucky Department of Transportation (DOT) to develop a new set of quality control/quality assurance concrete specifications, which were adopted by the Kentucky DOT. His interdisciplinary work in the area of "Creativity in Design" was recognized by the American Society for Engineering Education, and it received the Glen Martin Best Civil Engineering Paper Award. He has developed three new civil engineering courses at the University of Kentucky. In addition to over fifty peer-reviewed publications, he has published two chapters (on Superpave and Pavement Management) in a popular civil engineering textbook, "Pavement Analysis and Design", by Huang.

Dr. Mahboub provides administrative leadership by serving as the Director of Graduate Studies at the University of Kentucky. He has been recognized for his many achievements by receiving tenure, being promoted to the rank of full professor, and becoming the first Lawson Professor at the University of Kentucky; he is also an ASCE Fellow.

Rapidly Deployable System for the Structural Stabilization of Shock Damaged Structures

The overall objective of this research and development effort is to develop a system that is deployable with first responders capable of stabilizing blast-damaged structures. The system will consist of a delivery vehicle capable of both shotcreting and grouting pre-packaged rapid-hardening fiber reinforced cements, grouts, and micro-aggregated concretes. The system will provide the capability of stabilizing structures such as airport runways, tunnels, bridges, and dams that have been shocked and damaged by explosives before they fail catastrophically.

Presentation Slides



Project Description

- **Overall Purpose of project**
  - To develop a system that is deployable with first responders capable of stabilizing blast damaged structures. The system will consist of a delivery vehicle capable of applying rapid-hardening shotcrete.
- **Outcomes**
  - The system will provide the capability of stabilizing structures such as buildings, airport runways, tunnels, bridges and dams that have been shock-damaged by explosives.
- **Homeland Security Critical Infrastructure Protection – *DHS-NIHS Need***
  - 2003 Homeland Security Directive 7
  - Development of rapidly deployable automated response and fast recovery technologies that can be deployed by first responders to prevent catastrophic structural failure and to minimize disruption of critical infrastructure services.
- **Securing the Nation**
  - This work serves the mandate in NIPP for international collaboration. In particular with the coordinated research efforts with our colleagues in the United Kingdom to improve our protective capabilities.

Technical Assessment

- **Current Market Solutions**
  - Portland cement based solutions
    - Rate of strength development (compressive & tensile), short-term dimensional stability issues, cost of raw materials, very few are marketed for specialty shotcrete applications
  - Cumbersome shotcrete deployment systems
    - Not the right solution for rapid response and critical infrastructure restoration or protection
  - Current concrete solutions do not offer mobility AND ease of deployment necessary to deliver rapid hardening concrete to critical sites
    - must have both to meet the challenge

Technical Assessment

- **Final Product… will be a complete system**
  - A robust system, comprised of both unique cementitious materials and a delivery mechanism for the rapid stabilization.
    - **A new formulation for a shotcrete material**
    - **Rapid deployment system that utilizes new shotcrete materials**
    - **Single bag mix with good stability and a reasonable shelf life**

Project Tasks

- **Phase 1: Development of CSA Based Shotcrete**
  - Fabrication of Cements
    - rapid hardening & high strength & excellent bonding
  - Shotcrete Formulation and Materials Testing
    - CSA shotcrete mixes, fiber testing, shotcrete/substrate bond testing, shelf life of material

Project Tasks

- **Phase 2: Integration of Materials and Delivery Systems**
  - Selection of Transport Systems
    - Evaluation of wet and dry systems
  - Design Configuration of Final Prototype System
  - Evaluation of Final Materials and Prototype System
    - Field testing of prototype system, Testing of field emplaced materials, operational protocols, final prototype system design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Typical shotcrete operation

Cement & Concrete Factors

- **Rapid Hardening Cements**
  - Portland based cements currently used for rapid repair of surfaces
  - Can be fabricated from industrial and coal combustion by-products
    - **Three types of CSA cements will be studied:**
      - Calcium sulfate hemihydrate – "Plaster" Cements
      - Calcium sulfoferroaluminate (CSFA)
      - Calcium sulfoaluminate (CSA)

SEM image of ettringite crystals and fly ash in CSA cement mortar

$$Ca_4Al_6O_{12}SO_4 + 2CaSO_4{\bullet}2H_2O + 34H_2O \rightarrow Ca_6Al_2(SO_4)_3(OH)_{12}{\bullet}26H_2O + 4Al(OH)_3$$

(Klein's compound) (Gypsum) (Ettringite) (Aluminum hydroxide)

- Ettringite – cementitious phase responsible for high early strengths

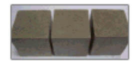
Cement & Concrete Factors

- **Bonding of Shotcrete to a Damaged Surface**
  - Interaction between shotcrete and damaged surface is very complex and important
    - Surface conditions, stresses produced by the weakened structure, exposed reinforcing steel, etc...
    - Polymer-modified shotcrete
- **Fiber-Reinforcement of Shotcrete**
  - Shotcrete is a brittle material
    - Fibers provide ductility
    - Types of fibers: Steel, Polymer


Damaged support column

Cement & Concrete Factors

- **Testing Progress to date:**
  - **Equipment**
    - Acquired dry-shotcrete system and compressor
  - **Laboratory Testing**
    - Material formulations
      - Pure compounds
      - CSA, CSFA, and Hemihydrate cements
      - Analyzed and testing reference materials
    - Bond strength testing
  - **Industry Collaboration**
    - Fibers, Admixtures, etc.


CSA


CSFA


Steel & Polymer Fibers

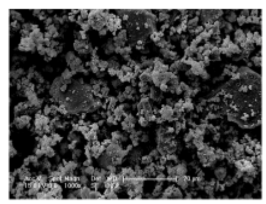
Delivery System

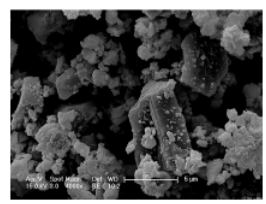
- **Integration of Materials and Delivery System**
  - System must be self contained, robust, and capable of operating in a stressed environment
    - Designed to quickly remedy problems
    - Develop Rapid strength


Gunnite Machine

Cement Hydration Study

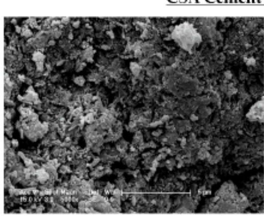
__CSA Cement A__ (unhydrated)

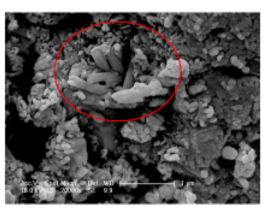




Cement Hydration Study

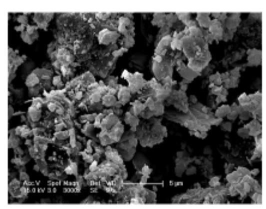
__CSA Cement A__ (1-day old)

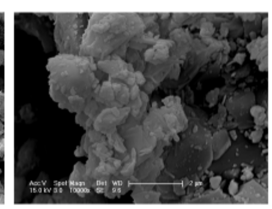

Dense Structure Already Formed

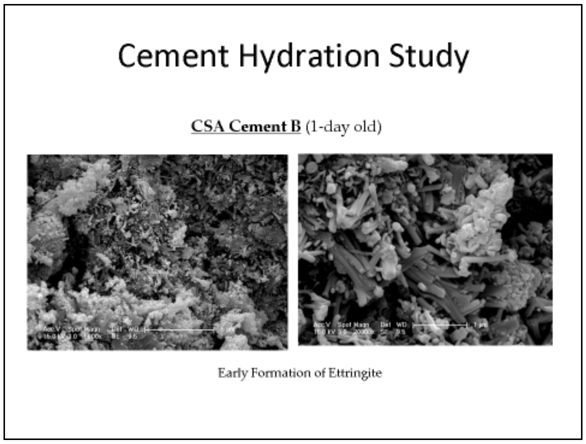

Initial Ettringite crystal formation

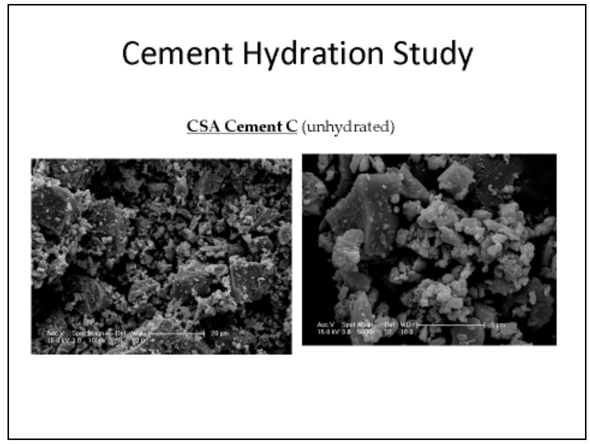
Cement Hydration Study

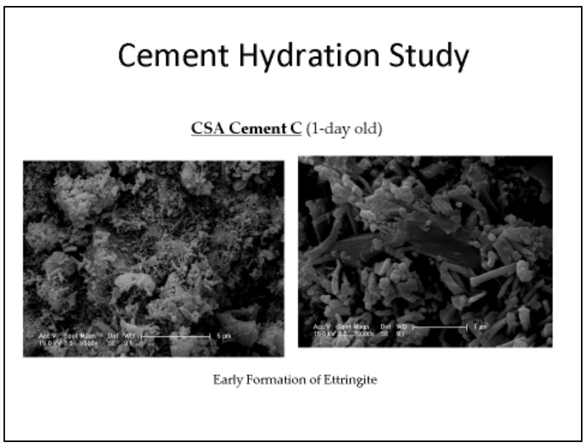
__CSA Cement B__ (unhydrated)

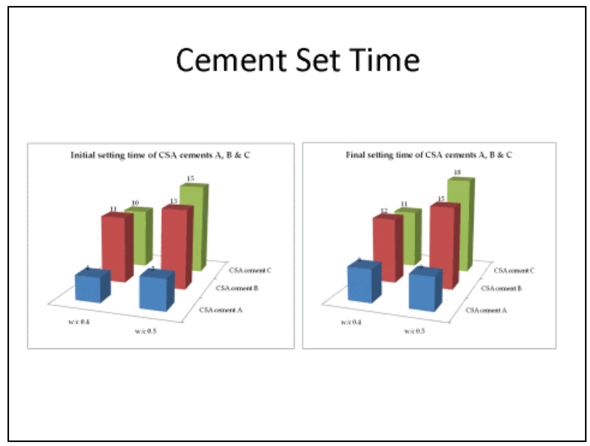


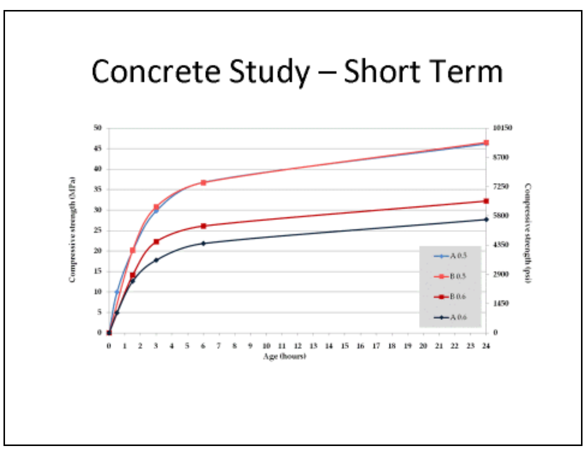


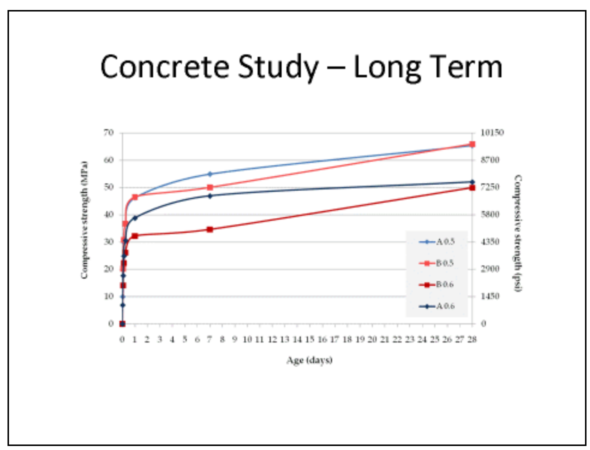

Cement Hydration Study
CSA Cement B (1-day old)
Early Formation of Ettringite


Cement Hydration Study
CSA Cement C (unhydrated)


Cement Hydration Study
CSA Cement C (1-day old)
Early Formation of Ettringite


Cement Set Time
Initial setting time of CSA cements A, B & C
Final setting time of CSA cements A, B & C

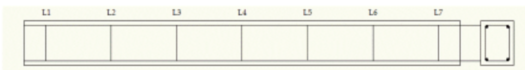

Concrete Study – Short Term
Compressive strength (MPa)
Compressive strength (psi)
Age (hours)


Concrete Study – Long Term
Compressive strength (MPa)
Compressive strength (psi)
Age (days)

Structural Beam Study

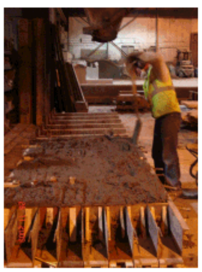
Substrate material:
- Structural quality concrete
- W/C ratio = 0.5
- Cement = 588 lbs/yd^3
- Cylinder strength= 5500 psi

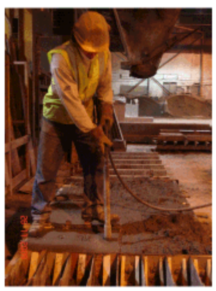
Beam size:
- Cast 10 beams (6x8x80 inches)
- Tension rebar 2x#4
- Shear rebar #2@12 in. centers
- Compression rebar 2x#4



Structural Beam Study

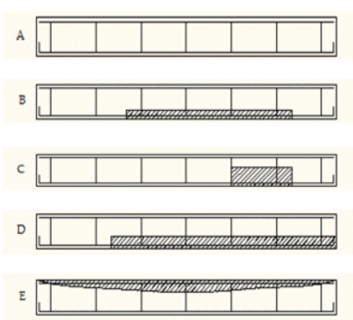
Structural Beam Study





Structural Beam Study

Structural Beam Study



Undamaged "Control"

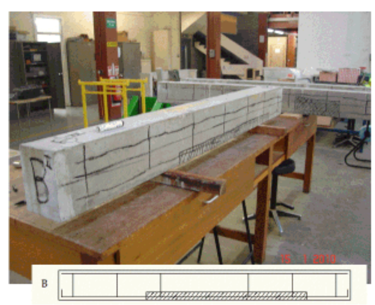
Partial tensile damage

Shear damage

Full tensile damage

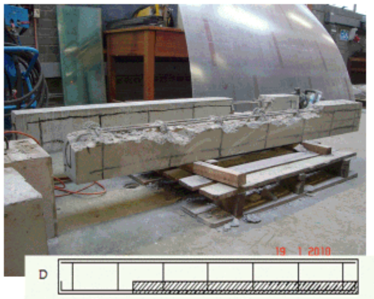
Compression damage

Structural Beam Study



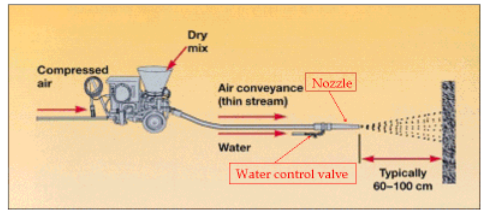
Partial Tensile Damage Zone

Structural Beam Study



Full Tensile Damage

Shotcrete Operation



Shotcrete Mix Design

- Sand dried at 140° F for 24 h
- Premixed CSA cement C
- Sand:Cement Ratio = 3:1
- Stored in 45 lbs bags
- Water:Solid Ratio controlled at the nozzle
- Estimated w/c ratio = 0.5
- Mix shot at 550 cfm and 175 psi

Shotcrete Equipment

Shotcrete Mix Design

Shotcrete Trial Panel

Extracting Trial Panel Specimen

Stabilizing Damaged Beams

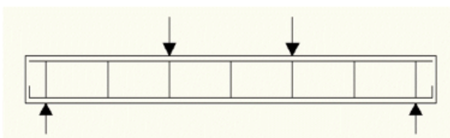
Experimenting with Fibers

Length: 2 in.
%Polymer Fibers: 0.25%

Uniform Distribution of Fibers

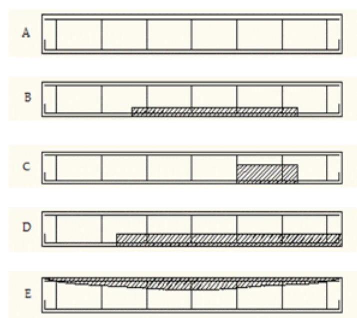
Structural Testing

Four-Point-Bend Testing



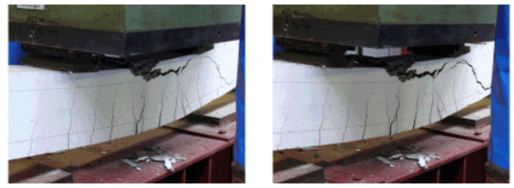
Structural Testing

Name	Description
A(I)	Undamaged
A(II)	Undamaged
B(I)	Damaged & sprayed
B(II)	Damaged
C(I)	Damaged & sprayed
C(II)	Damaged
D(I)	Damaged & sprayed
D(II)	Damaged
E(I)	Damaged & sprayed
E(II)	Damaged



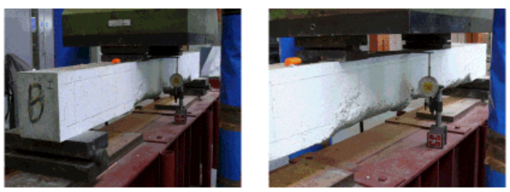
Reference Beam (Beam A)

Reference Beam (Beam A) At Maximum Deflection



Note: Equal distribution of tensile cracks leading to a shear crack on the right side.

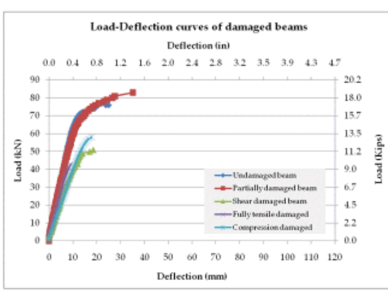
Stabilized Beam (Beam B)



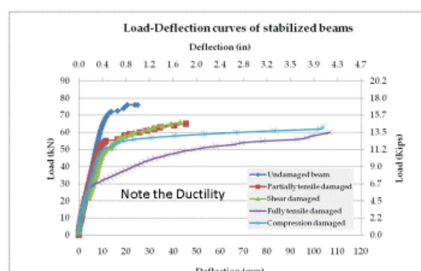
Stabilized Beam (Beam B) At Maximum Deflection

Note: The sprayed CSA concrete has been well bonded to the substrate (there is no detachment) and the loaded beam reacts with well distributed tensile and shear cracks.

Structural Behavior of Beams Before Stabilization



Structural Behavior of Beams After Stabilization – Note Ductility



Future Research Directions

- **Complex Structures**
  - Steel, Concrete, Composite
  - Full Scale Structural Instrumentation
  - Monitoring of Stabilized Structures
  - Development of Stabilization Protocols for Complex Structures
- **Final Restoration/Demolition**

Collaborative Opportunities

Industry & Research

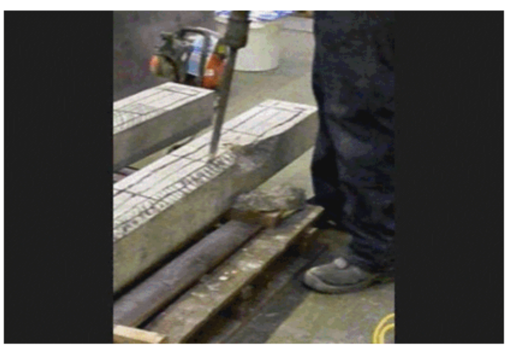
- **Minova USA**
  - Formulation and delivery of grouts and mortars
- **University of Dundee & University of Aberdeen**
- **Buzzi Unicem USA, Inc.** (Greencastle, IN)
  - International multi-regional group focused on cement, ready-mix concrete and aggregates. U.S. company that produces commercially available CSA cement.
- **Propex, Inc.** (Chattanooga, TN)
  - World's largest producer of geosynthetic, concrete, industrial fabrics and fiber
- **Shotcrete Services Inc.** (Madisonville, KY)
  - Experts in shotcrete technical services and training
- **U.S. Army Corps of Engineers**

Technology Commercialization

- **Potential Strategies**
  - Serve Strategic Markets, Responders or Front-Line Agencies (Security Sector)
  - Technology Transfer
    - DHS/FEMA – Search and Rescue
    - Department of Defense
    - United States Army Corps of Engineers
    - Construction – Mining Industry – Critical applications

Technology Commercialization

- **Partner – License Model – General Industry**
- **Near Term – Minova, USA, Inc.**
  - Partner in the research and specs of the system
  - Develop Products for …
    - DHS applications
    - Mining applications, etc.
- **Long Term – Infrastructure Related Industries**
  - Kentucky and nationwide



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Jon Rigolo

Jon Rigolo is a Captain with the Virginia Beach Fire Department where he is assigned to the Fire Training Division and oversees recruit and technical rescue training. He is a Rescue Team

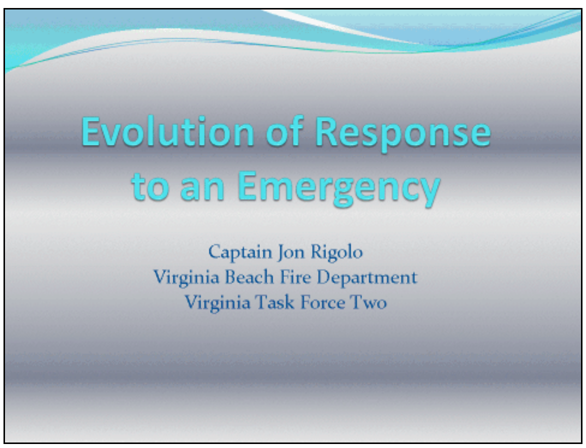
Manager for Virginia Task Force Two, one of the 28 FEMA Urban Search and Rescue (US&R) teams, and has deployed with them to several large disasters including the Pentagon response in 2001. Captain Rigolo is also a member of the FEMA Incident Support Team (IST) and deployed with them to Texas during Hurricane Ike. Captain Rigolo instructs nationally and internationally on the subject of technical rescue including collapse rescue and is a FEMA-certified instructor. Mr. Rigolo is also a Partner of Spec Rescue International, an emergency response training, consulting and risk management company.

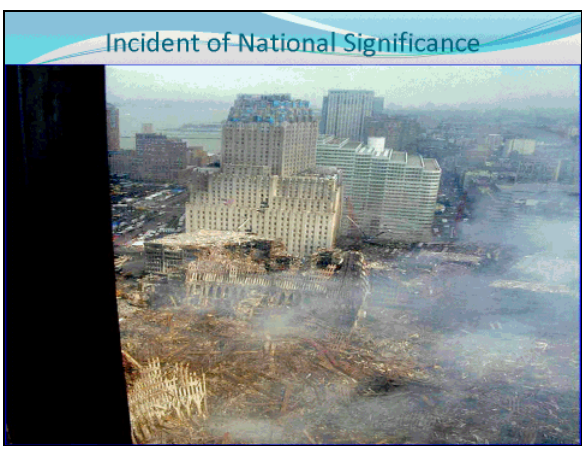
Evolution of Response to an Emergency

As DHS S&T develops new tools and techniques related to Post-IED Building Stabilization, it is important that researchers and engineers have an understanding of how the response to a large-scale incident evolves from the first-due engine company responding to 911 calls to a full-scale Unified Command controlled disaster response, including insight into the types of decisions that are made at each level of response.

This presentation includes an overview of the typical steps that would occur as local, State, and Federal responders bring personnel, tools, and resources to bear as they respond to an IED attack. Ddecisions relating to building stability at each stage of response are also addressed.

Presentation Slides





Alfred P. Murrah Federal Building April 19, 1995

USA Events with IED's

- This type of incident is rare
- Most initial responders will not see the event as a IED/Bomb issue unless told so or responding to an at risk building
- World Trade Center (93)
- Abortion Clinic in Atlanta with secondary device (97)

Local Responders

- Prior to 2001 "locals" may not have collapse rescue training
- Post 2001 most jurisdictions have at a minimum "awareness' level collapse rescue training
- Local abilities and resources vary greatly from town to town
- Focus of all initial responders is RESCUE! As a rule first responders will do whatever is necessary to perform rescues!

First due responders will

- Start initial incident stabilization
- Remove "surface" victims first
- Remove "lightly" trapped victims
- Stabilize building (shoring or selected debris removal)
- Find and remove trapped (buried) victims

Incident Command System (ICS)

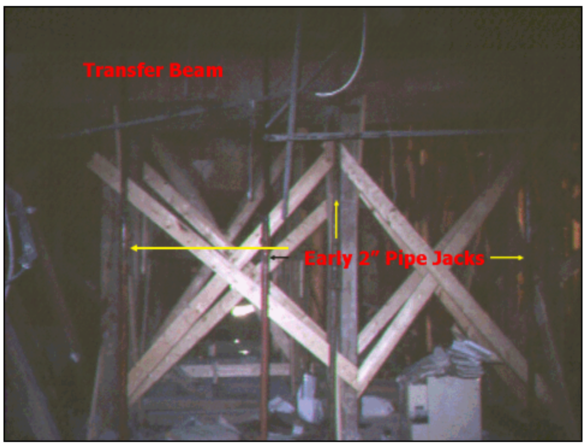
- Initial Command established by first arriving Officer
- ICS is expanded to suit the size of the incident
- Locals will request assistance when the scope of the incident overwhelms the on scene units
- First call: Regional Team
- Second call: State or EMAC teams
- Third call: Federal USAR teams

What we need to know from you (engineer dudes)

- How stable is the building now!
- What will happen when we start debris removal
- What will happen when weather affects the building
- What type, size and strength of shore is needed to stabilize the building
- If debris are shifted in the building what will happen?

Oklahoma City Bombing
19 April 1995
Alfred P. Murrah Federal Building

Pentagon September 2001



Transfer Beam
Early 2" Pipe Jacks

Questions ?

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Dean Tills

In 1993 Dean joined the Fairfax County Virginia Urban Search and Rescue Task Force. As the lead engineer on the task force he has participated in rescue operations after the Oklahoma City Bombing; Hurricane Fran; the earthquakes in Turkey, Taiwan, and Iran; the Attack on the Pentagon; Hurricane Katrina; the Haitian School Collapse; and the Haiti Earthquake. He has also been a subject matter expert for the US&R Structures Specialist Training, Structural Collapse Technician and Technical Search Specialist Training Courses.

Dean graduated from the University of Maryland in 1983 with a degree in Civil Engineering and became licensed in 1989. Dean is currently a senior associate for Robert Silman Associates in Washington, DC. His engineering background includes working for contractors and consulting engineering firms in the design and construction of new buildings, forensic evaluations, and earthquake resistance studies. He was selected by Engineering News Record (Construction Industry Magazine) as one of the 25 Top Newsmakers – 2002, for activities at the Pentagon in 2001 and received a Public Service Award from the American Society of Civil Engineers for his search and rescue work.

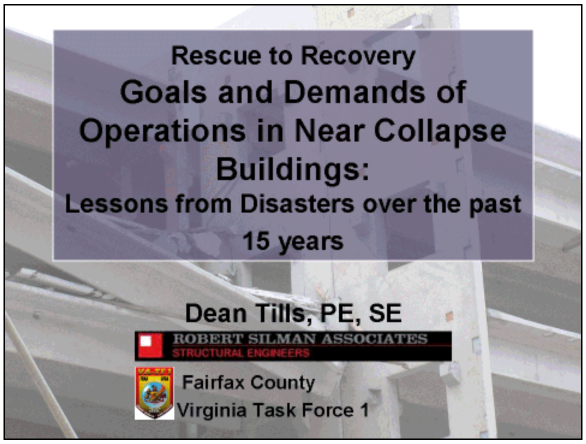
Goals and Demands of Operations in Near-Collapse Buildings: Case Studies from Disasters over the Past 15 Years

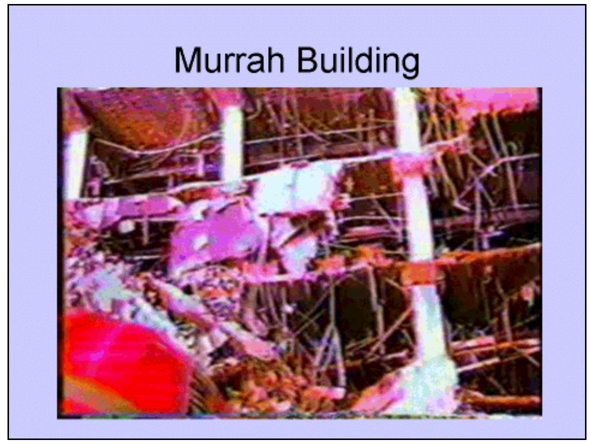
This presentation explores the rescue and stabilization activities at several disasters in relation to safety and operational progress. Discussions present the interaction between operational engineers and emergency personnel and highlight:

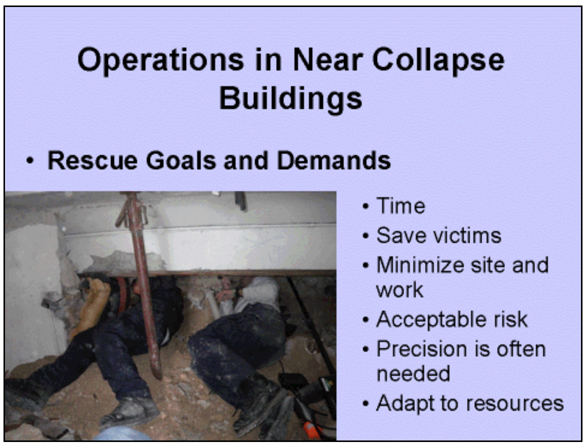
- Command authority and limited resource issues during operations.
- Stabilization equipment and expected operational duration and effectiveness.
- The required interaction between rescue and recovery phase personnel.
- The advantages of eye witness intelligence and an on-site knowledge base in operations.
- The implications of untested or ineffective testing of new technologies that are intended to assist in rescue and/or recovery operations.
- The impacts of different training pathways and operational goals with respect to rescue and recovery personnel.

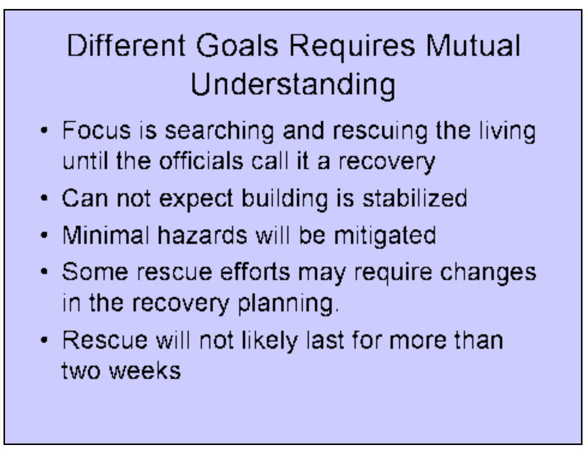
These discussions are based on first-hand experience from disasters such as Oklahoma City, Pentagon, and earthquakes in several foreign countries, and on evaluations of the activities after the Kenya Embassy Bombing and a local building collapse in order to provide an understanding of the goals, obstacles and level of risk to stabilization of a near-collapse structure.

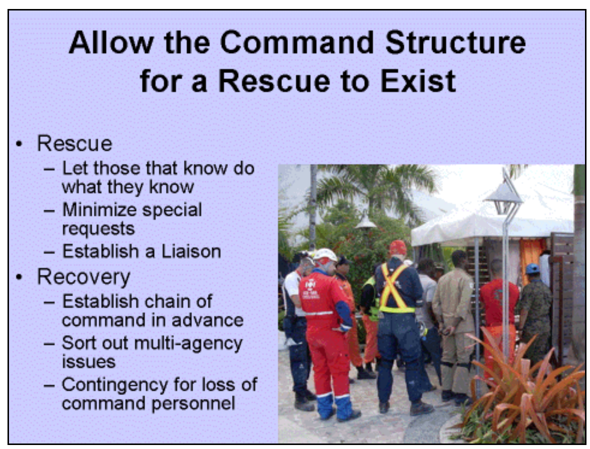
Presentation Slides

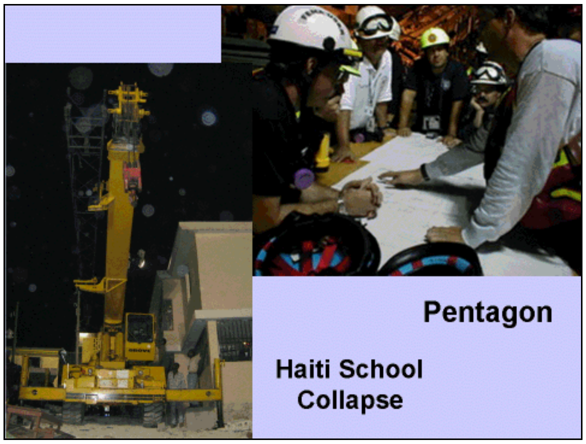




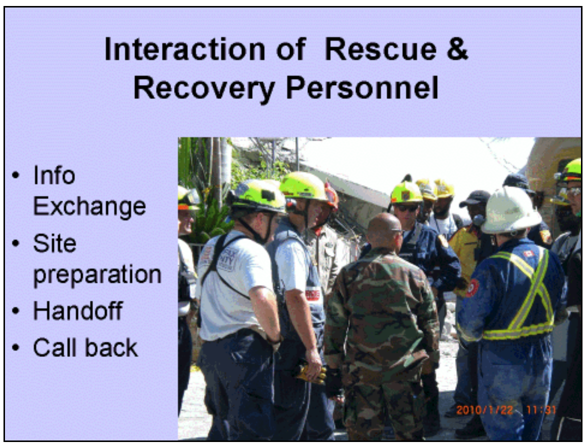


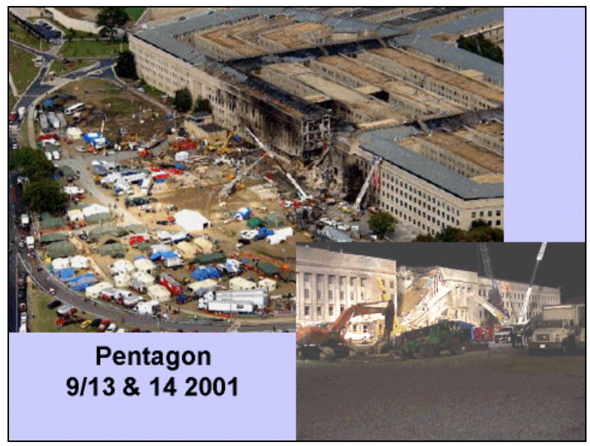




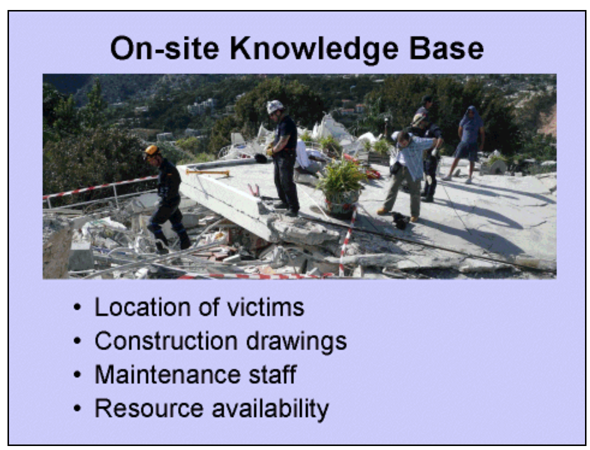

Pentagon
Haiti School
Collapse


Sometimes the event gets bigger than we expect


Interaction of Rescue & Recovery Personnel
• Info Exchange
• Site preparation
• Handoff
• Call back


Pentagon
9/13 & 14 2001


Pentagon
call back
09-24-01


On-site Knowledge Base
• Location of victims
• Construction drawings
• Maintenance staff
• Resource availability

On Site Knowledge Base

- Pentagon – water shutoff, resources and drawings
- OKC – Victim locations and drawings
- Taiwan, Turkey, Haiti School – Victim locations, manpower
- Haiti, Montana Hotel – Victim locations, drawings, resource contacts

Limited Resource Issues During Initial Operations

- Minimum resources
- Distracting occurrences
- Inappropriate resources

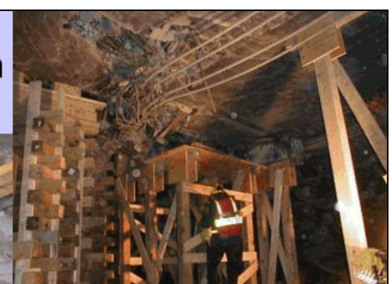
Walk-on vs. Trained Personnel

- Rescue vs. Recovery
- Dangerous Assumptions
- Goals and Responsibilities uncertain

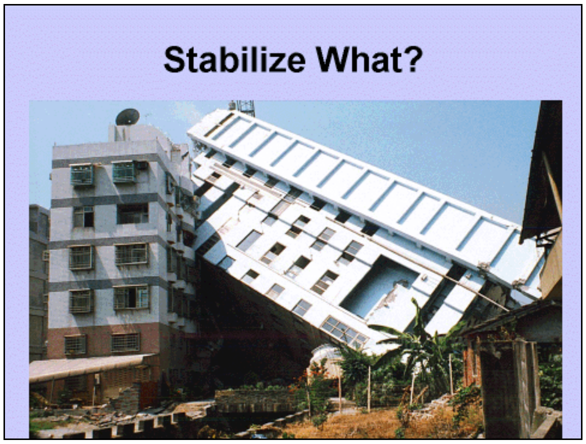
Stabilization Rescue vs. Recovery

- Duration and effectiveness
- Large vs. small sites
- Get-r-done
- Working surfaces

Pentagon



- Haiti School Collapse

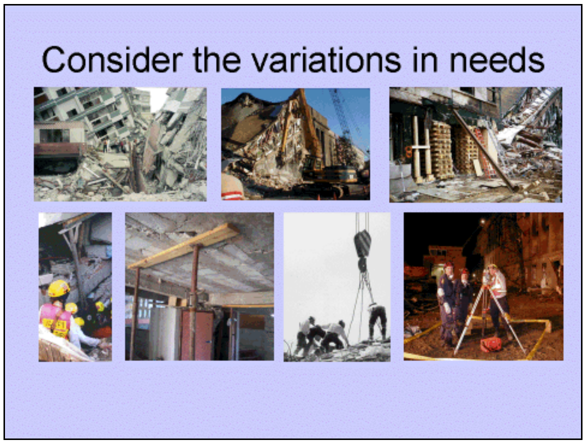

Stabilize What?

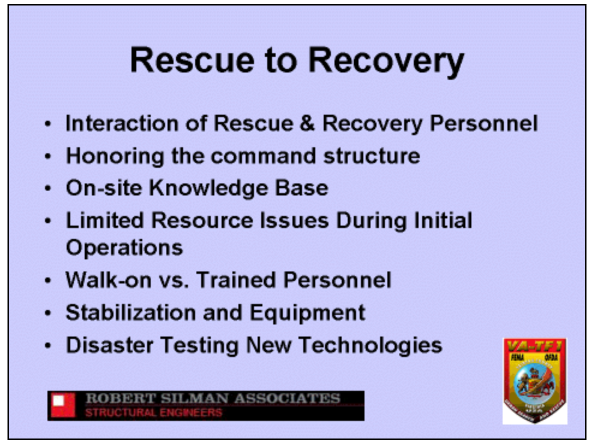

NIH Garage
2005


Equipment
Rescue vs.
Recovery
• Wrecking ball vs. hammer
• Duration and effectiveness
• Large vs. small sites
• Debris removal plans


Disaster Testing
New
Technologies
• Cautious testing ground
• "Side Effects" must be known
• Disaster testing should only be the final stamp


Haiti EQ





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Scott Nacheman

Scott G. Nacheman is a Vice President in the Chicago office of the international engineering and building technology firm Thornton Tomasetti where he specializes in building investigations, failure analysis as well as restoration/repair design.

Mr. Nacheman serves as a Structures Specialist with Illinois US&R Task Force 1 as well as DHS/FEMA US&R IN-TF1 and the FEMA US&R IST Blue. He is a Field Instructor for the Illinois Fire Service Institute where he collaborated on the development and delivery of the Structural Collapse Rescue Technician program. Scott also serves as a responder for the Northbrook (IL) Fire Department and MABAS Division III Technical Rescue Teams.

Scott's interest in disaster mitigation is a result of his over 18 years experience working with the fire service in New York and Illinois, where he has served as a Firefighter, Lieutenant and Instructor.

Mr. Nacheman is currently involved in several University-based research projects related to emergency response and post-disaster evaluations of structures. In addition he serves as an Advisory Member to the Illinois Terrorism Task Force and is currently involved with the development disaster engineering resource typing and training for the American Society of Civil Engineers (ASCE) Committee on Critical Infrastructure.

Scott is a Certified Fire and Explosion Investigator and is also a Member of Technical Committees of the National Fire Protection Association (NFPA), Society of Fire Protection Engineers (SFPE), American Institute of Architects (AIA) and the National Council of Structural Engineers Associations (NCSEA).

Scott received masters degrees in both Architecture and Civil Engineering from the University of Illinois at Urbana-Champaign.

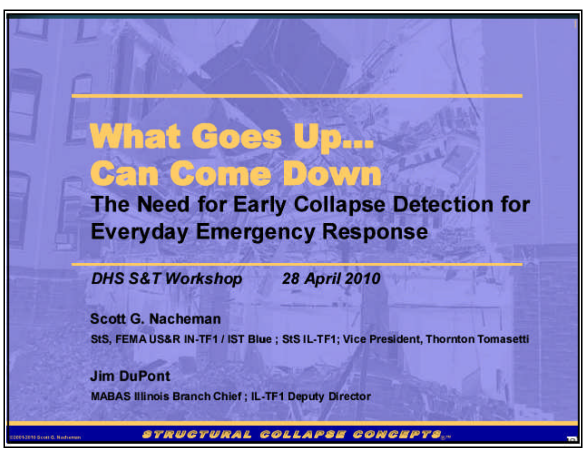
Collapse Case Study and Technology Transfer Opportunities

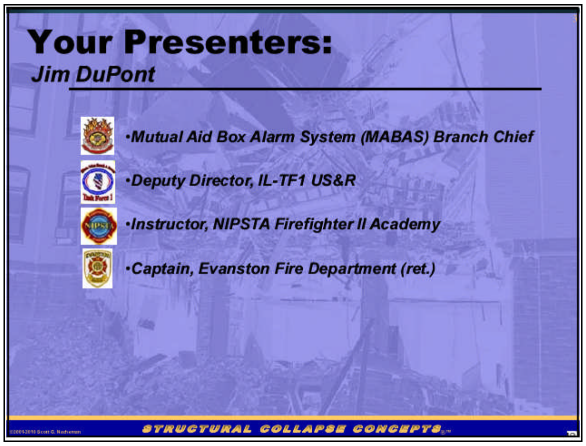
The author presents a case study of a building collapse incident involving a secondary collapse that occurred while first responders were on scene conducting search operations. The collapse incident involved an occupied multi-story steel and concrete parking structure attached to a partially occupied mid-rise condominium building. A progressive collapse of several bays occurred throughout four stories of the structure.

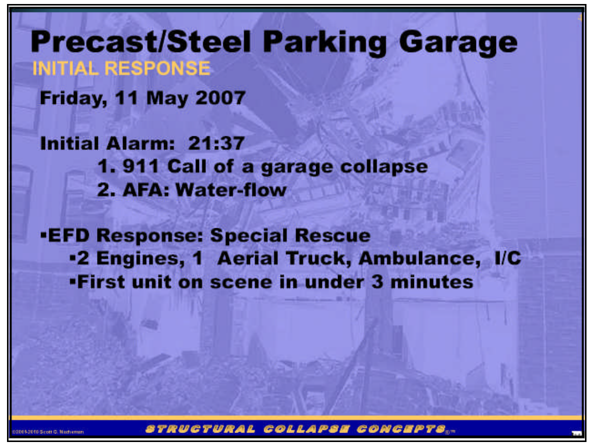
The nature of the initial collapse, the emergency response, and the author's involvement during the secondary collapse incident are discussed with a focus on the need for improved instantaneous information gathering regarding structural integrity and overstress conditions. Researchers and other stakeholders will benefit from a discussion of the type of 'everyday' emergency responses that can benefit from the development of real-time sensors and systems for collapse detection.

Moreover, the author presents a brief overview of two current University-based research projects on which he worked in an advisory capacity. The focuses of the systems include Radio Frequency Identification systems for building triage management and Digital Image Correlation for structural movement detection. In addition, a third project involving ultra-sensitive GPS monitoring with applicability to the field of collapse detection in compromised buildings is discussed.

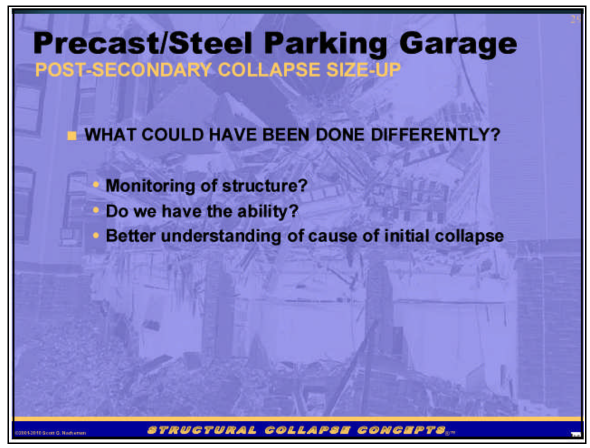
Presentation Slides




Your Presenters:
Jim DuPont
•Mutual Aid Box Alarm System (MABAS) Branch Chief
•Deputy Director, IL-TF1 US&R
•Instructor, NIPSTA Firefighter II Academy
•Captain, Evanston Fire Department (ret.)
STRUCTURAL COLLAPSE CONCEPTS

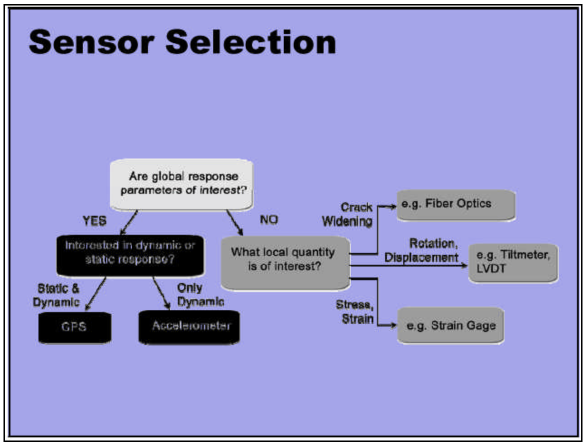

Precast/Steel Parking Garage
INITIAL RESPONSE
Friday, 11 May 2007
Initial Alarm: 21:37
1. 911 Call of a garage collapse
2. AFA: Water-flow
•EFD Response: Special Rescue
•2 Engines, 1 Aerial Truck, Ambulance, I/C
•First unit on scene in under 3 minutes
STRUCTURAL COLLAPSE CONCEPTS

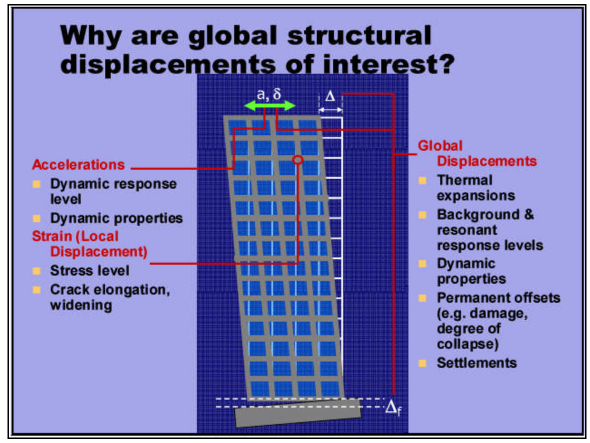

---IMAGES NOT FOR PUBLIC RELEASE---
STRUCTURAL COLLAPSE CONCEPTS

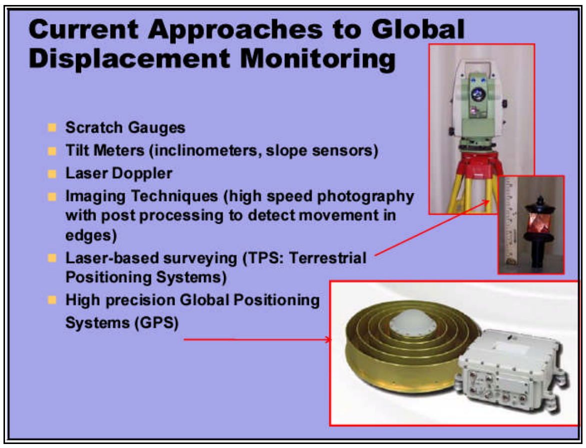

Precast/Steel Parking Garage
POST-SECONDARY COLLAPSE SIZE-UP
WHAT COULD HAVE BEEN DONE DIFFERENTLY?
Monitoring of structure?
Do we have the ability?
Better understanding of cause of initial collapse
STRUCTURAL COLLAPSE CONCEPTS

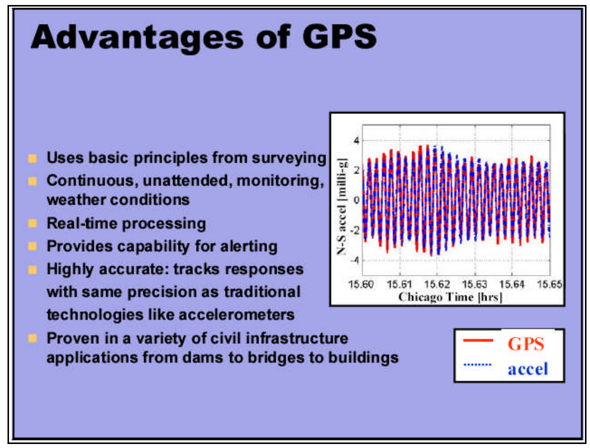

Opportunities for Technology
SECONDARY COLLAPSE DETECTION
Ground Station GPS
Digital Image Correlation
STRUCTURAL COLLAPSE CONCEPTS

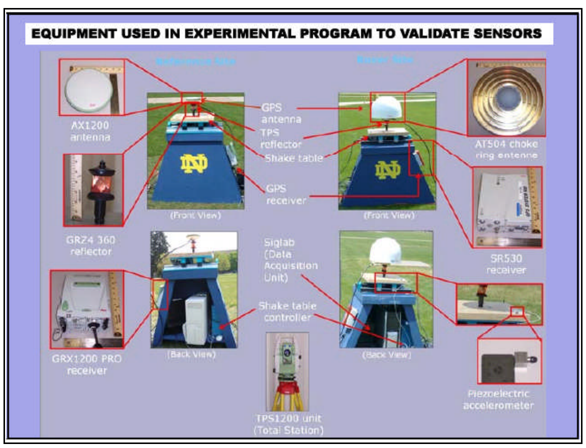

Technologies to Monitor Full-Scale Structural Responses
Research and Development of:
Dr. Tracy Kijewski-Correa
Department of Civil Engineering and Geological Sciences
University of Notre Dame
Structural DYNAmics & MOnitoring Laboratory

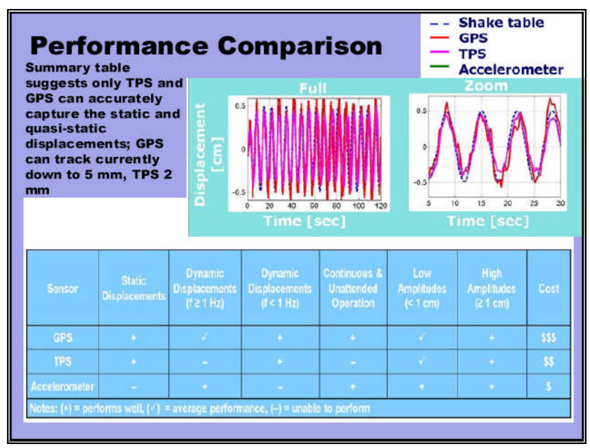












Sensor	Static Displacements	Dynamic Displacements (f ≥ 1 Hz)	Dynamic Displacements (f < 1 Hz)	Continuous & Unattended Operation	Low Amplitudes (< 1 cm)	High Amplitudes (≥ 1 cm)	Cost
GPS	+	✓	+	+	✓	+	$$$
TPS	+	–	+	–	✓	+	$$
Accelerometer	–	+	–	+	+	+	$

Notes: (+) = performs well, (✓) = average performance, (–) = unable to perform

Secondary Building Collapse Detection Using Digital Image Correlation

Mary E. Murphy
Industrial and Enterprise Systems
UROP Summer 2007
Prof. John Lambros
Dr. Gavin Horn
Scott G. Nacheman

Sponsors
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Protecting the First Responders

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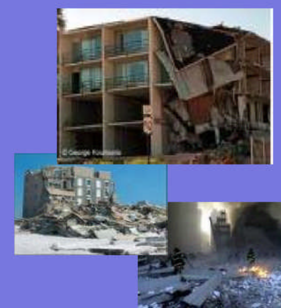
- Many structures partially collapse after natural or man-made disasters.
- First responders enter the buildings to save anyone trapped inside.
- Current systems used to detect and alert if secondary collapse is imminent, so rescuers can exit safely, have certain drawbacks.



Current Methods Of Secondary Building Collapse Detection

40

- Transits, Theodolites, and Total Station Devices
  - Single point measurement
  - Operator necessary at all times
  - Less accurate
- Wireless Building Monitoring System
  - Small number of location monitored
  - Cumbersome batteries
  - Contact with structure necessary to attach monitors

Is DIC suitable for building collapse detection?

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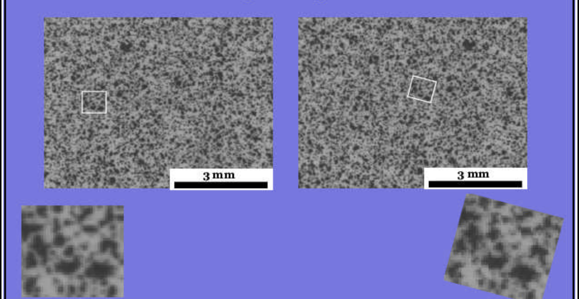
- Full Field measurements
- High precision
- Easy to use, software based
- Eventually, no contact with structure necessary

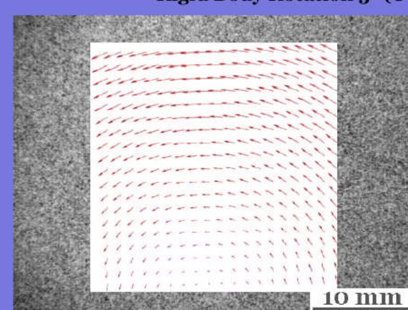
What is Digital Image Correlation (DIC)?

42



43

Example: Rigid Body Rotation 5° (CCW)



Research Needed

- Uniform lighting
- Nice pattern
- Vibration isolation
- Automation

GOALS

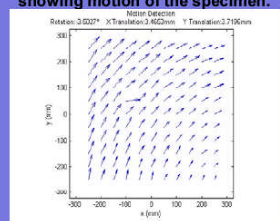
- Create user-friendly interface in MATLAB
- Add all processes into one program
- Assess degree of feasibility for project

Pre-processing

- Motion estimate needed in DIC is done by letting the user click on the characteristic areas in the deformed and undeformed images.
- Input file to existing DIC codes - both Coarse/Fine and Newton Raphson automatically generated

Post-Processing

Interface prompts user to measure specimen in order to get translation in millimeters, and generates an arrow plot showing motion of the specimen.



Outputs the translation detected in both x and y directions and the rotation.
Warning message displayed if translation > 30 mm or rotation > 10°.

Feasibility

- Real time pace; MATLAB program is too slow for the final product, may be faster if interface was written in a different language.
- Non-contact; A procedure, that requires no touching of structure, is needed to measure specimen in images.

QUESTIONS?

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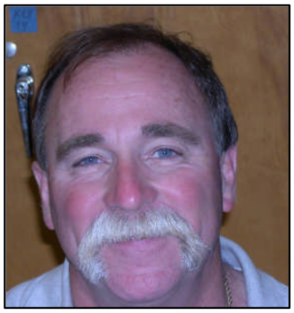
dupont@mabas-il.org

STRUCTURAL COLLAPSE CONCEPTS

• • •

John O'Connell



John has recently retired from the City of New York Fire Department after 26 years of service. For the last 18 years he was assigned to the departments Collapse Rescue Company No. 3.

John is a principle member of the NFPA 1670 committee program and is the task group chair for the structural collapse section. A former task force leader for New York City's US&R Task Force 1, He has been on several FEMA development committees in the past 15 years, as well as a lead instructor for the FEMA rescue specialist training. John also serves as a member of the FEMA Incident Support Team at major disasters. He is an author of numerous articles on structural collapse and technical rescue, and also the book Emergency Rescue Shoring Techniques. He was also a member of the FDNY command staff at the World Trade Center Incident, John was in charge of all underground search and rescue operations as well as the FDNY liaison with the contractors. He operated at the site continually for 5 months.

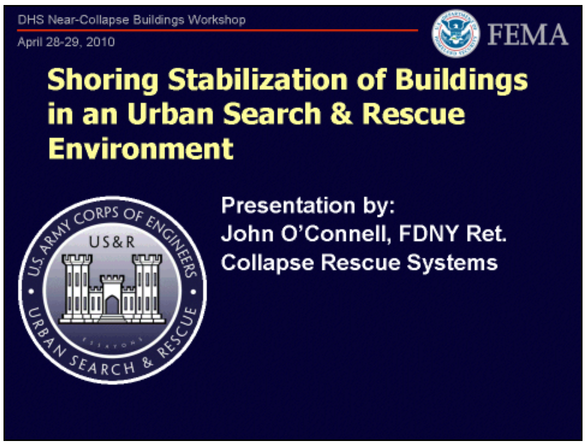
He has spent extensive time over the last 15 years in curriculum development for the FDNY, the NY State Office of Fire Prevention and Control, and the FEMA Urban Search & Rescue system. John is the lead shoring instructor for the FEMA US&R system as well as the U.S. Army Corps of Engineers US&R branch.

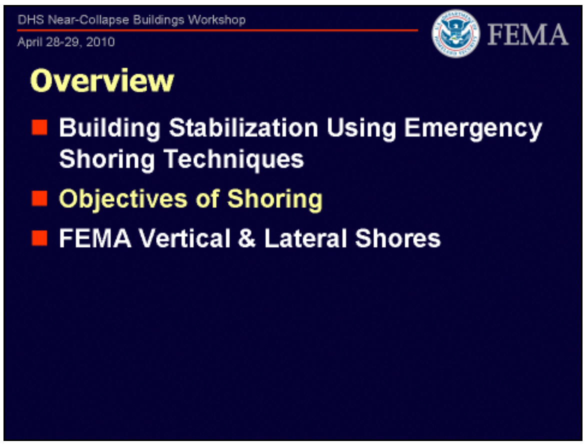
John is the president of Collapse Rescue Systems Inc., an international training company specializing in technical rescue. John has taught extensively throughout the country as well as Canada, China, Germany, the Middle East and Japan.

Emergency Rescue Shoring Concepts

This presentation shows the current state of Emergency Rescue Shoring being implemented by the FEMA Urban Search & Rescue System, as well as the national standard for responding with firefighting assets. The hows and whys of this method are discussed.

Presentation Slides





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FEMA

Assessing the Damaged Structure

- The StS and the Rescuers must work together!
- Several options to reduce risk and exposure
  - Avoid the Hazard
  - Remove the Hazard
  - Minimize Exposure to the Hazard
  - Monitor the Hazard
  - Shore the Hazard
- Shoring is costly in regards to time, personnel & material resources

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Emergency Shoring

- What Is Emergency Shoring?
- Why Use Emergency Shoring?
- What are effective shoring techniques

WE INSTALL RESCUE SHORING TO PROTECT "US"

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Why Use Emergency Shoring?

- It is a means to support and redistribute collapse loads, while providing a means to stabilize the immediate area of the damaged structure – especially near victim locations
- Allows rescue operations to proceed with less risk
- Provides structural redundancy and warning of overloads

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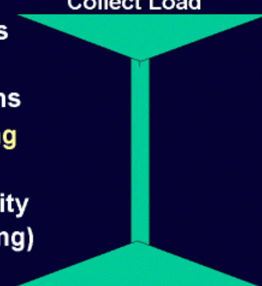
Vertical Shore Principles

- Need Posts / Shores with Adjustability & Positive Connections
- Need Lateral Bracing
- Need System with Forgiveness (Ductility and overload warning)



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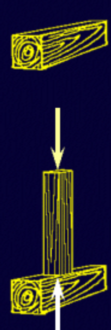
Use Unique Property of Timber

To Provide Warning of Overload

- Growth pattern of Tree
- Rapid growth in spring deposits relatively soft fiber
- Slower growth rate in summer deposits more dense fiber
- If load end grain, crushing strength is determined by summerwood
- If load is on side (crossgrain), soft springwood determines strength
- Crossgrain bearing failure is slow & noisy - (gives warning)



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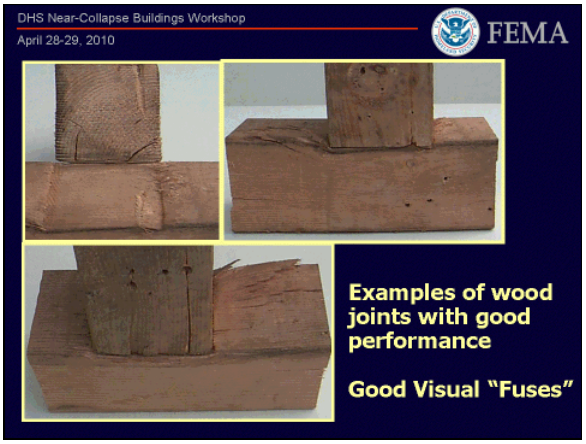
Capacity of Wood Posts

- For L/D to be 25 or Less
  - 4 x 4 should be kept shorter than 8 feet
  - 6 x 6 should be kept shorter than 12 feet
- This is not always possible
- If a post is properly braced at its mid-height, it's Effective length is half it's Total length.
  - Bracing must be placed in N-S as well as E-W direction and properly nailed
- FEMA, US&R shoring has lots of bracing



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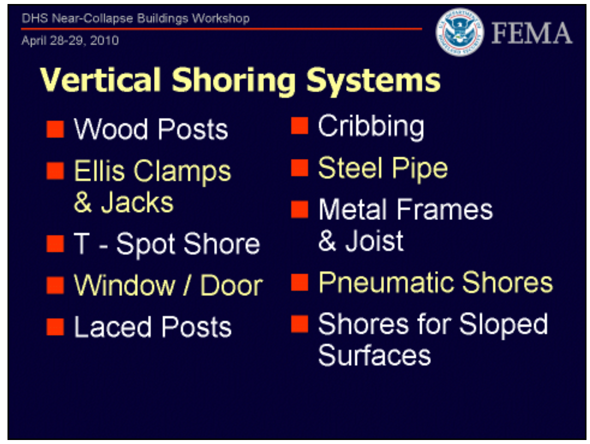
Examples of wood joints with good performance
Good Visual "Fuses"



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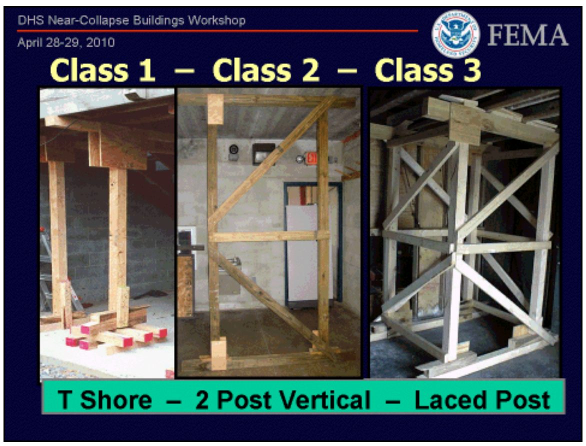
Vertical Shoring Systems
Wood Posts
Ellis Clamps & Jacks
T - Spot Shore
Window / Door
Laced Posts
Cribbing
Steel Pipe
Metal Frames & Joist
Pneumatic Shores
Shores for Sloped Surfaces



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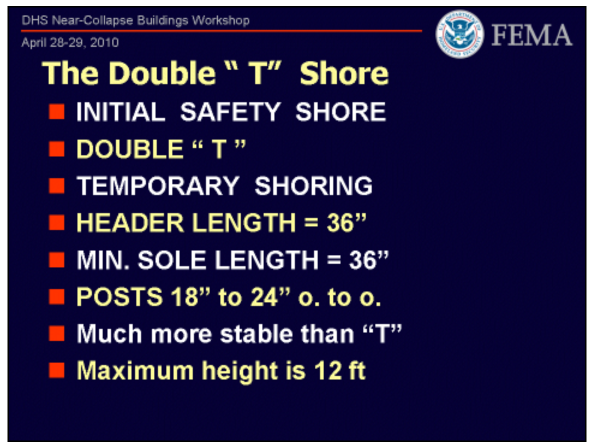
Class 1 – Class 2 – Class 3
T Shore – 2 Post Vertical – Laced Post



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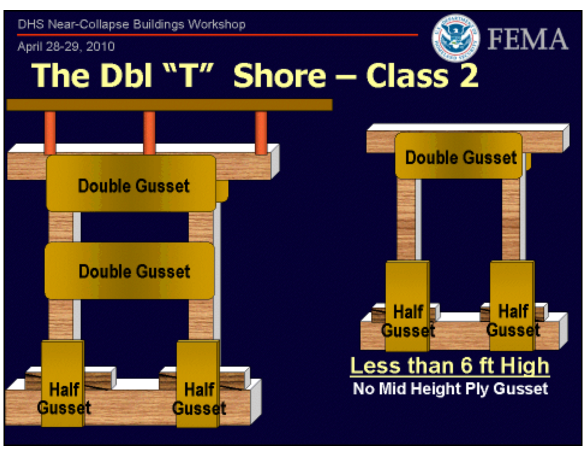
The Double " T" Shore
INITIAL SAFETY SHORE
DOUBLE " T "
TEMPORARY SHORING
HEADER LENGTH = 36"
MIN. SOLE LENGTH = 36"
POSTS 18" to 24" o. to o.
Much more stable than "T"
Maximum height is 12 ft



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The Dbl "T" Shore – Class 2
Double Gusset
Double Gusset
Half Gusset
Half Gusset
Double Gusset
Half Gusset
Half Gusset
Less than 6 ft High
No Mid Height Ply Gusset

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FEMA
Dbl "T" Shore – easy to install
Shore Top Chord of Truss
Shore Wood Apartment

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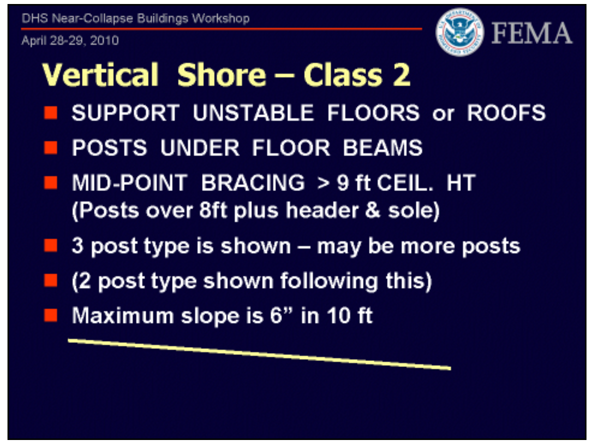

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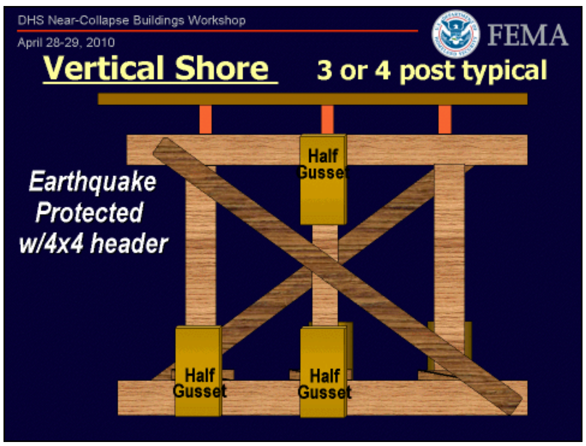
Vertical Shore – Class 2
SUPPORT UNSTABLE FLOORS or ROOFS
POSTS UNDER FLOOR BEAMS
MID-POINT BRACING > 9 ft CEIL. HT
(Posts over 8ft plus header & sole)
3 post type is shown – may be more posts
(2 post type shown following this)
Maximum slope is 6” in 10 ft



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Vertical Shore
3 or 4 post typical
Earthquake
Protected
w/4x4 header
Half
Gusset
Half
Gusset
Half
Gusset

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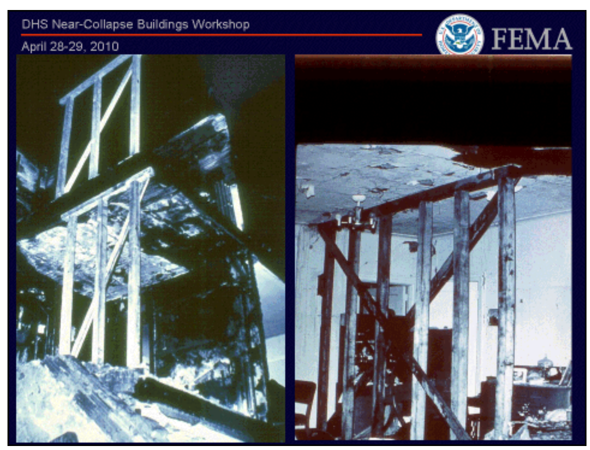

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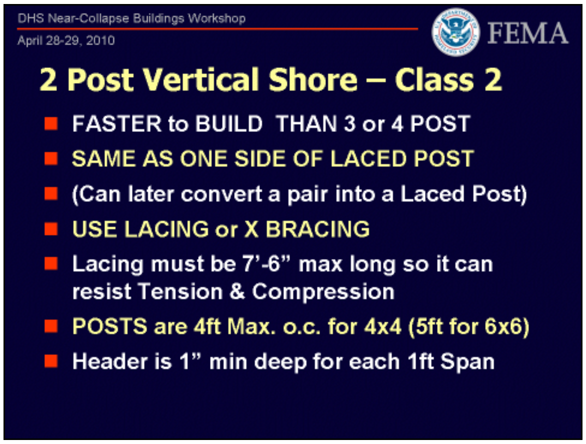
DHS Near-Collapse Buildings Workshop
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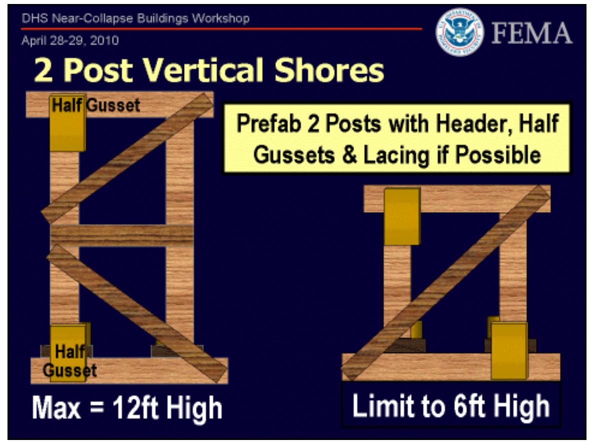
2 Post Vertical Shore – Class 2
FASTER to BUILD THAN 3 or 4 POST
SAME AS ONE SIDE OF LACED POST
(Can later convert a pair into a Laced Post)
USE LACING or X BRACING
Lacing must be 7'-6" max long so it can resist Tension & Compression
POSTS are 4ft Max. o.c. for 4x4 (5ft for 6x6)
Header is 1" min deep for each 1ft Span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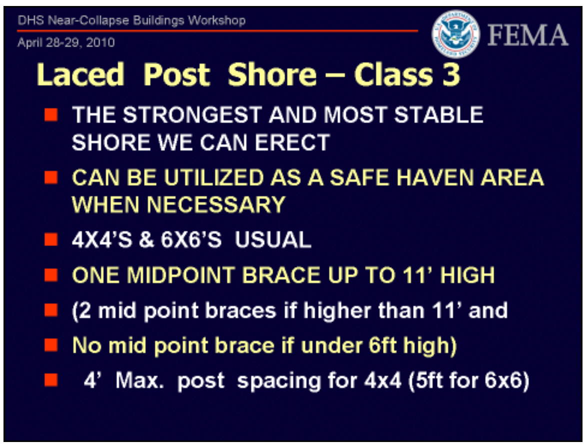
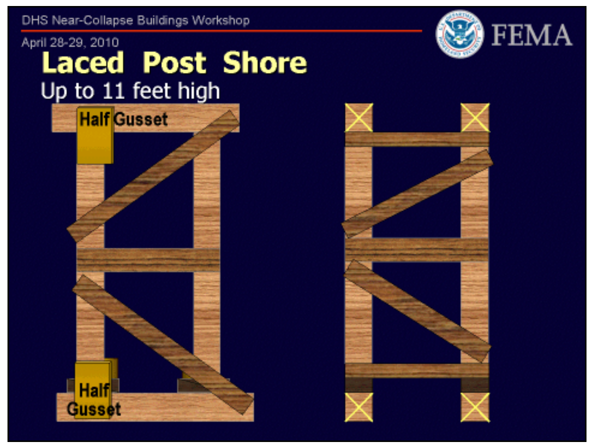
2 Post Vertical Shores
Half Gusset
Prefab 2 Posts with Header, Half Gussets & Lacing if Possible
Half Gusset
Max = 12ft High
Limit to 6ft High


DHS Near-Collapse Buildings Workshop
April 28-29, 2010
FEMA
Laced Post Shore – Class 3
THE STRONGEST AND MOST STABLE SHORE WE CAN ERECT
CAN BE UTILIZED AS A SAFE HAVEN AREA WHEN NECESSARY
4X4'S & 6X6'S USUAL
ONE MIDPOINT BRACE UP TO 11' HIGH
(2 mid point braces if higher than 11' and
No mid point brace if under 6ft high)
4' Max. post spacing for 4x4 (5ft for 6x6)


DHS Near-Collapse Buildings Workshop
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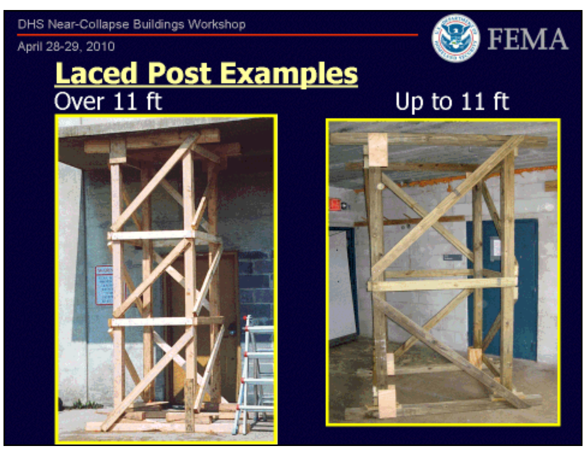
FEMA
Laced Post Shore
Up to 11 feet high
Half Gusset
Half Gusset


DHS Near-Collapse Buildings Workshop
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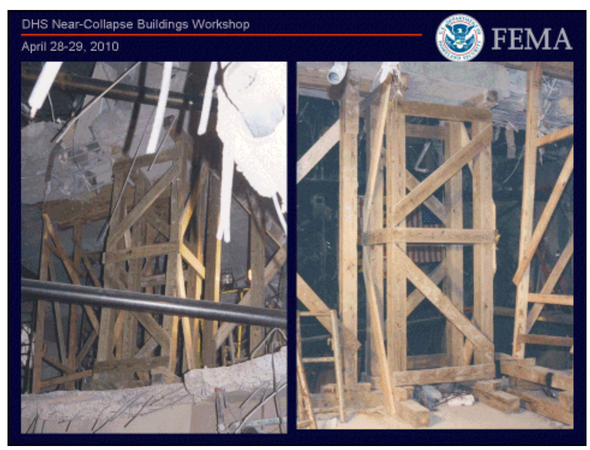
FEMA
Laced Post Examples
Over 11 ft
Up to 11 ft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Lateral Shoring Systems

- Horizontal Shores
- Trench Shores
- Raker Shores
- Tiebacks

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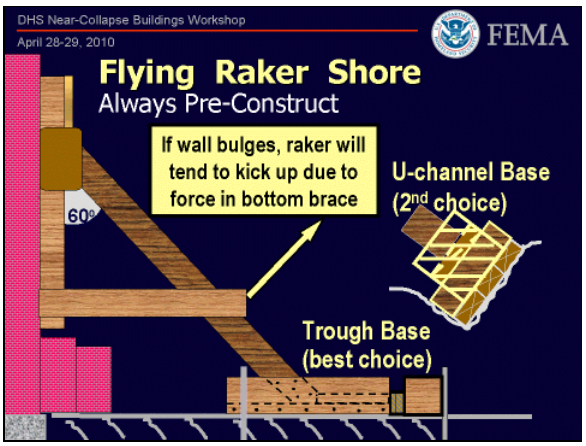
Flying Raker Shore – Spot Shore

- AN INITIAL SAFETY RAKER SHORE
- MUST BE ANCHORED TO THE WALL TO WORK PROPERLY
- NOT A PERMANENT SYSTEM!
- USE TROUGH BASE - CAN BE REUSED
  - (2nd choice is U-Cannel, but need to dig-in in danger zone)
- Use 6ft Wall Plate w/24"cleat & 60deg Raker
- Design Strength is about 1000lb



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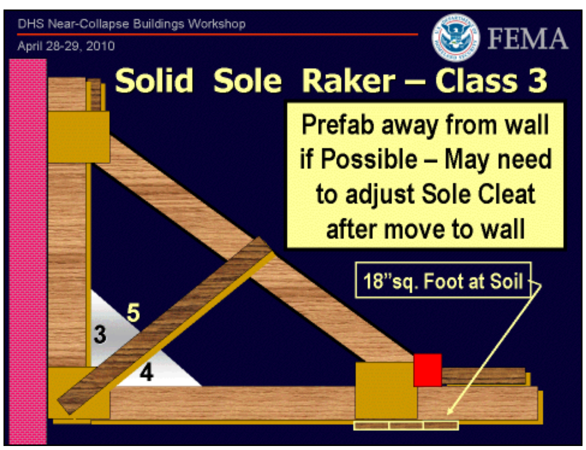
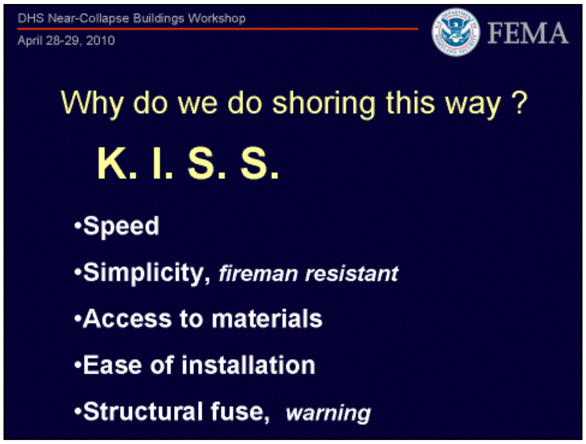
Solid Sole Raker – Class 3

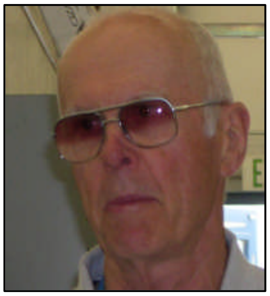
- The Raker Shore of Choice
- Generally erected at 45 degree angle (60 deg O.K.)
- Can be utilized on Soil as well as Pavement
  - Add 18" sq. foot under intersection of raker/sole on Soil
- Pre-assemble and carry into position
- Must erect minimum of two shores
- Used to re-support unstable or leaning walls
- Design Strength is 2,500lb each, 5,000lb pair





• • •

David Hammond



David graduated from the University of California, Berkeley in 1954 with a B.S.C.E., and was engaged in the design of seismically resistant structures in the San Francisco Bay Area from 1957 to 2000. He served in the U.S. Army from Jan 1955 to Jan 1957, and was stationed at Ft. Belvoir in the spring of 1955. While serving in the Army he began his instructional career as a Troop Information & Education NCO.

In 1985, he began his involvement in Urban Search and Rescue as the leader of the U.S. Search Dog Team 3 at the Mexico City Earthquake. Since that time, David has continued as a support member of California Rescue Dog Association in numerous other disasters.

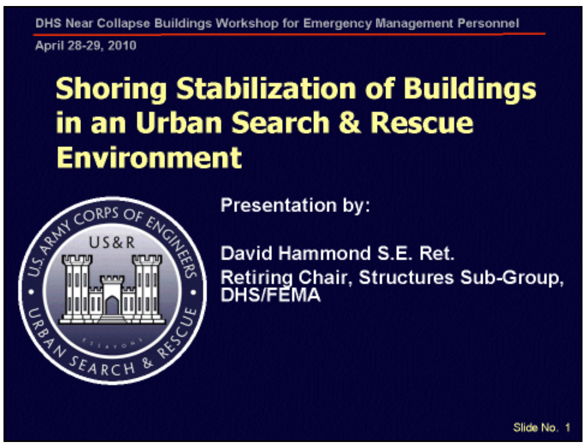
He was an original member of the FEMA US&R Advisory Committee and is the current Chair of the DHS/FEMA US&R Structures Sub-group. He is a lead instructor for the USACE-DHS/FEMA Structural Specialists (StS) training program, as well as other FEMA US&R training courses. He was a lead StS for the FEMA response to the Oklahoma City Bombing incident, the Puerto Rico Gas Explosion in 1996, and the World Trade Center Collapse in 2001. As member of the FEMA US&R White Incident Support Team (IST) he has responded to many hurricanes. He is a member of DHS/FEMA's CA-TF-3 located in Menlo Park, California.

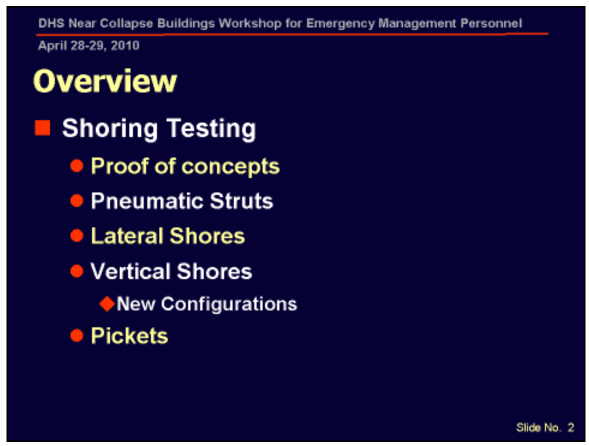
Destructive Testing of Near-Collapse Mitigation Measures: Wood Shoring, Metal Adjustable Struts, Steel Jackets, and Expansion Anchors

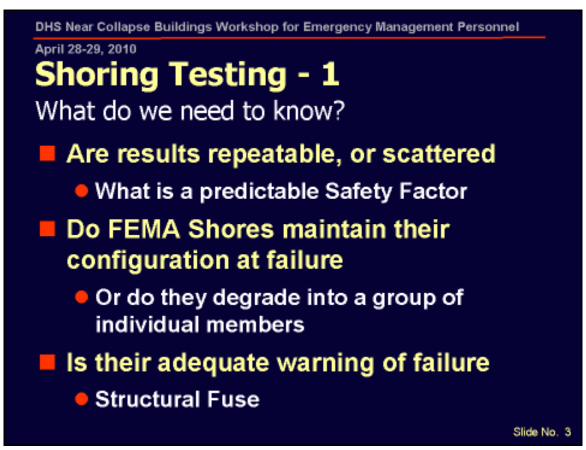
The United States has been preparing to respond to building damage or collapse events for two decades. The main catastrophic events of concern are natural disasters, such as earthquakes, or industrial accidents, such as explosions and terrorism events. A partially collapsed or otherwise compromised structure with a potential for further collapse endangers rescue personnel while rescue operations are in progress. The FEMA US&R System has developed standards for vertical and lateral support elements that provide redundancy to compromised structures. These elements include wood shoring, metal adjustable struts, steel pickets, and expansion anchors. It is important that all involved in a response understand the capacity of these elements as well as their performance behavior. Since the loadings that may be imposed on these elements by severely compromised structures may not be accurately determined, or may change or shift with time, it is important to ensure that their failure modes are ductile, repeatable, and observable in the field.

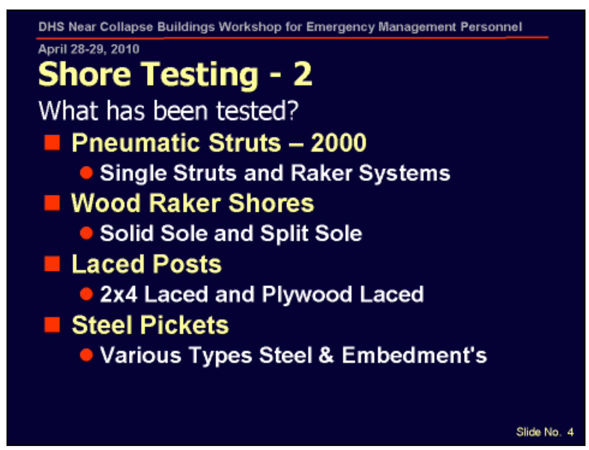
A testing program, developed and conducted by the FEMA US&R Structures Sub-Group, was initiated in 2000. It has filled the need of providing vital design data for these simple and sometimes complex supporting elements. In addition, the testing has given rescuers and the engineers who support them the ability to observe the performance of these elements under severe loading. This presentation describes the testing program, and explains how it has helped to improve the design and use of the various mitigation systems. It also indicates the future direction of the testing program.

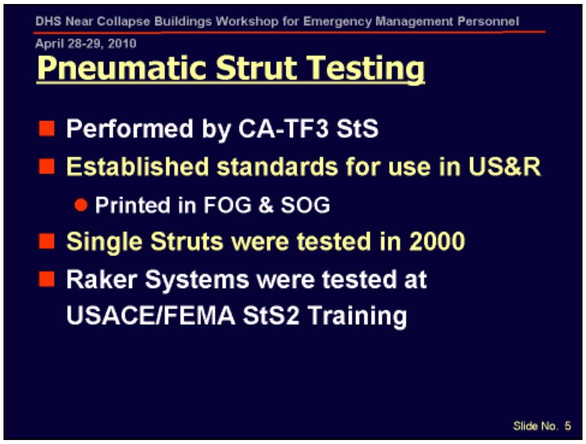
Presentation Slides

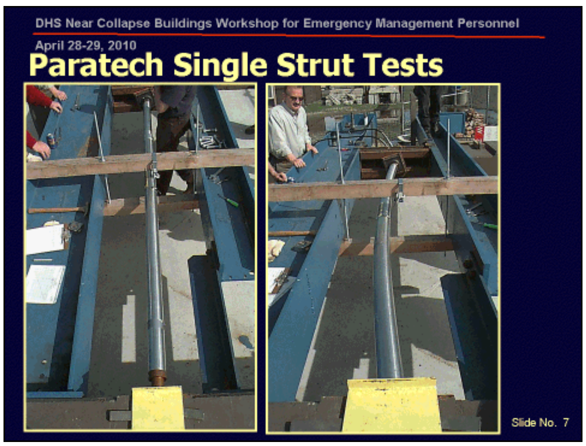


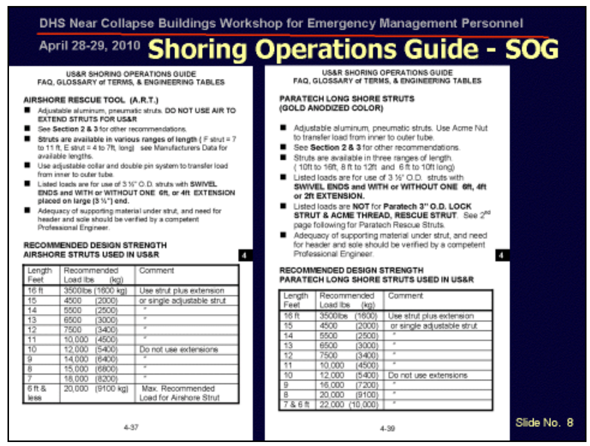












US&R SHORING OPERATIONS GUIDE
FAQ, GLOSSARY of TERMS, & ENGINEERING TABLES

AIRSHORE RESCUE TOOL (A.R.T.)

- Adjustable aluminum, pneumatic struts. **DO NOT USE AIR TO EXTEND STRUTS FOR US&R**
- See **Section 2 & 3** for other recommendations.
- **Struts are available in various ranges of length** (F strut = 7 to 11 ft, E strut = 4 to 7ft, long) see Manufacturers Data for available lengths.
- Use adjustable collar and double pin system to transfer load from inner to outer tube.
- Listed loads are for use of 3 ½" O.D. struts with **SWIVEL ENDS and WITH or WITHOUT ONE 6ft, or 4ft EXTENSION placed on large (3 ½") end.**
- Adequacy of supporting material under strut, and need for header and sole should be verified by a competent Professional Engineer.

RECOMMENDED DESIGN STRENGTH AIRSHORE STRUTS USED IN US&R

4

Length Feet	Recommended Load lbs (kg)	Comment
16 ft	3500lbs (1600 kg)	Use strut plus extension
15	4500 (2000)	or single adjustable strut
14	5500 (2500)	"
13	6500 (3000)	"
12	7500 (3400)	"
11	10,000 (4500)	"
10	12,000 (5400)	Do not use extensions
9	14,000 (6400)	"
8	15,000 (6800)	"
7	18,000 (8200)	"
6 ft & less	20,000 (9100 kg)	Max. Recommended Load for Airshore Strut

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US&R SHORING OPERATIONS GUIDE
FAQ, GLOSSARY of TERMS, & ENGINEERING TABLES

PARATECH LONG SHORE STRUTS (GOLD ANODIZED COLOR)

- Adjustable aluminum, pneumatic struts. Use Acme Nut to transfer load from inner to outer tube.
- See **Section 2 & 3** for other recommendations.
- Struts are available in three ranges of length. (10ft to 16ft, 8 ft to 12ft and 6 ft to 10ft long)
- Listed loads are for use of 3 ½" O.D. struts with **SWIVEL ENDS and WITH or WITHOUT ONE 6ft, 4ft or 2ft EXTENSION.**
- Listed loads are **NOT** for **Paratech 3" O.D. LOCK STRUT & ACME THREAD, RESCUE STRUT**. See 2nd page following for Paratech Rescue Struts.
- Adequacy of supporting material under strut, and need for header and sole should be verified by a competent Professional Engineer.

4

RECOMMENDED DESIGN STRENGTH PARATECH LONG SHORE STRUTS USED IN US&R

Length Feet	Recommended Load lbs (kg)	Comment
16 ft	3500lbs (1600)	Use strut plus extension
15	4500 (2000)	or single adjustable strut
14	5500 (2500)	"
13	6500 (3000)	"
12	7500 (3400)	"
11	10,000 (4500)	"
10	12,000 (5400)	Do not use extensions
9	16,000 (7200)	"
8	20,000 (9100)	"
7 & 6 ft	22,000 (10,000)	"

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April 28-29, 2010

Airshore Raker Test Failure

Slide No. 11

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April 28-29, 2010

Shoring Operations Guide - SOG

US&R SHORING OPERATIONS GUIDE
FAQ, GLOSSARY of TERMS, & ENGINEERING TABLES

PARATECH LONG STRUT RAKER SHORE SYSTEM

- System is made from 2 rakers spaced 8ft max. apart with X bracing. See **Section 3.**
- **Use 6 to 10 ft or 8 to 12 ft struts With or Without one 2ft, 4ft, or 6ft extension per strut.**
- Raker Systems should be configured with the angle between the Raker and the Ground being between 40 and 60 degrees.
- Add 12" long, 4" high, ½" thick angles to Base Plates to provide a vertical bearing surface.
- Rakers should be attached to the wall surface and restrained at the ground as in timber systems.
- The Safe Working Strength for a pair of Paratech Rakers used in US&R should be determined by a US&R Structure Specialist from the following chart:
  (Safe Horizontal load at Point of Insertion)

RECOMMENDED DESIGN STRENGTH
PARATECH RAKER SYSTEM at 45degrees

Raker Length	Height to Point of Insertion	Horizontal Load on 2 Rakers w/ X-bracing
16 ft	11.0 ft	5000 lbs (2300 kg)
15 ft	10.5 ft	6400 lbs (2900 kg)
14 ft	10.0 ft	7800 lbs (3500 kg)
13 ft	9.0 ft	9200 lbs (4200 kg)
12 ft	8.5 ft	10,600lbs (4800 kg)

PARATECH RAKER SYSTEM at 60degrees

16 ft	13.8 ft	3500 lbs (1600 kg)
15 ft	13.0 ft	4500 lbs (2000 kg)
14 ft	12.0 ft	5500 lbs (2500 kg)
13 ft	11.3 ft	6500 lbs (3000 kg)
12 ft	10.4 ft	7500 lbs (3400 kg)
11 ft	9.5 ft	10,000 lbs (4500 kg)

4-40

US&R SHORING OPERATIONS GUIDE
FAQ, GLOSSARY of TERMS, & ENGINEERING TABLES

AIRSHORE RAKER SHORE SYSTEM

- System is made from 2 rakers spaced 8ft max. apart with X bracing. See **Section 3**
- **Use adjustable struts With or Without one 4ft or 6ft extension per strut, placed on large end**
- Raker Systems should be configured with the angle between the Raker and the Ground being between 40 and 60 degrees.
- Add 12" long, 4" high, ½" thick angles to Base Plates to provide a vertical bearing surface.
- Rakers should be attached to the wall surface and restrained at the ground as in timber rakers.
- The Safe Working Strength for a pair of Airshore Rakers used in US&R should be determined by a US&R Structure Specialist from the following chart:
  (Safe Horizontal load at Point of Insertion)

RECOMMENDED DESIGN STRENGTH
AIRSHORE RAKER SYSTEM at 45degrees

Raker Length	Height to Point of Insertion	Horizontal Load on 2 Rakers w/ X-bracing
16 ft	11.0 ft	5000 lbs (2300 kg)
15 ft	10.5 ft	6400 lbs (2900 kg)
14 ft	10.0 ft	7800 lbs (3500 kg)
13 ft	9.0 ft	9200 lbs (4200 kg)
12 ft	8.5 ft	10,600lbs (4800 kg)

AIRSHORE RAKER SYSTEM at 60degrees

16 ft	13.8 ft	3500 lbs (1600 kg)
15 ft	13.0 ft	4500 lbs (2000 kg)
14 ft	12.0 ft	5500 lbs (2500 kg)
13 ft	11.3 ft	6500 lbs (3000kg)
12 ft	10.4 ft	7500 lbs (3400 kg)
11 ft	9.5 ft	10,000 lbs (4500 kg)

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Slide No. 12

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Wood Raker Shore Testing

- Performed at USACE/FEMA StS2 Training
  - CATF-3 Training Site
  - Raker Breaker was funded by SEAONC
- Proof of concept
- Verified Safety Factor and Failure Mode
- Demonstrated Large S.F. of Systems
- Solid Sole & Split Sole Systems

Slide No. 13

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Test Setup for Raker Shores

Slide No. 14

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Solid Sole Raker – 17 Tests

Remove Nails - Force Failure in Cleat

Slide No. 15

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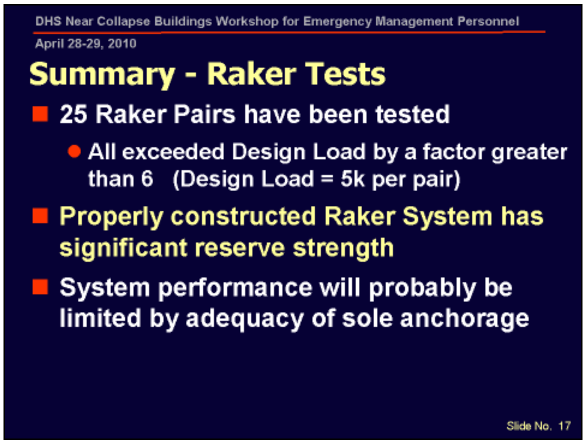
Split Sole Raker – 8 Tests

Remove Foot - Force Failure in Trough Base

Slide No. 16


DHS Near Collapse Buildings Workshop for Emergency Management Personnel
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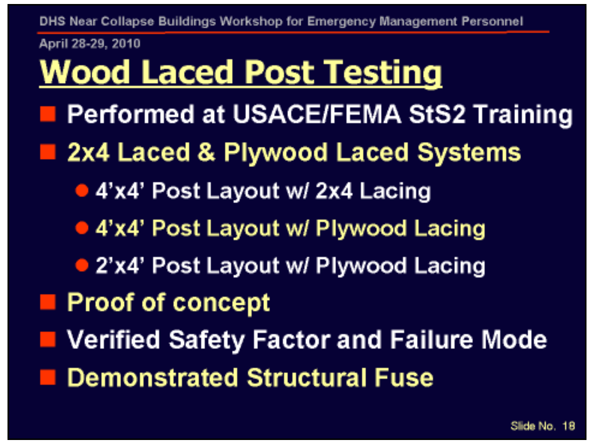
Summary - Raker Tests
25 Raker Pairs have been tested
All exceeded Design Load by a factor greater than 6 (Design Load = 5k per pair)
Properly constructed Raker System has significant reserve strength
System performance will probably be limited by adequacy of sole anchorage
Slide No. 17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Wood Laced Post Testing
Performed at USACE/FEMA StS2 Training
2x4 Laced & Plywood Laced Systems
4'x4' Post Layout w/ 2x4 Lacing
4'x4' Post Layout w/ Plywood Lacing
2'x4' Post Layout w/ Plywood Lacing
Proof of concept
Verified Safety Factor and Failure Mode
Demonstrated Structural Fuse
Slide No. 18


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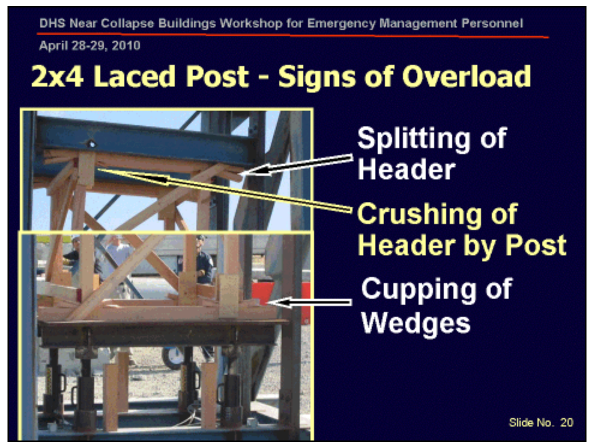
Vertical Load Shore Tester
US&R Training Site, Moffett Field, CA
Laced Post
Plywood Laced Post
Slide No. 19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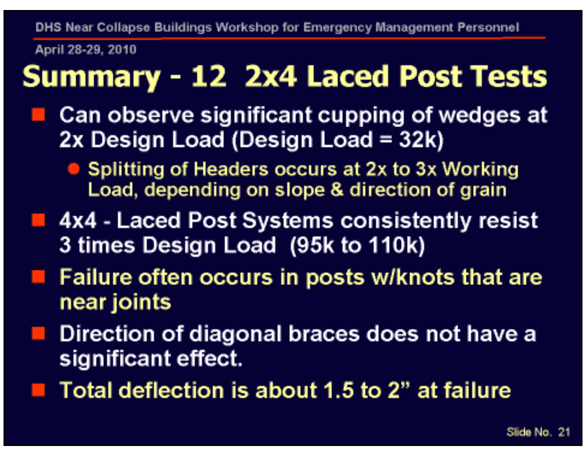
2x4 Laced Post - Signs of Overload
Splitting of Header
Crushing of Header by Post
Cupping of Wedges
Slide No. 20


DHS Near Collapse Buildings Workshop for Emergency Management Personnel
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Summary - 12 2x4 Laced Post Tests
Can observe significant cupping of wedges at 2x Design Load (Design Load = 32k)
Splitting of Headers occurs at 2x to 3x Working Load, depending on slope & direction of grain
4x4 - Laced Post Systems consistently resist 3 times Design Load (95k to 110k)
Failure often occurs in posts w/knots that are near joints
Direction of diagonal braces does not have a significant effect.
Total deflection is about 1.5 to 2" at failure
Slide No. 21


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PLP-52 – 4'x4' 100k


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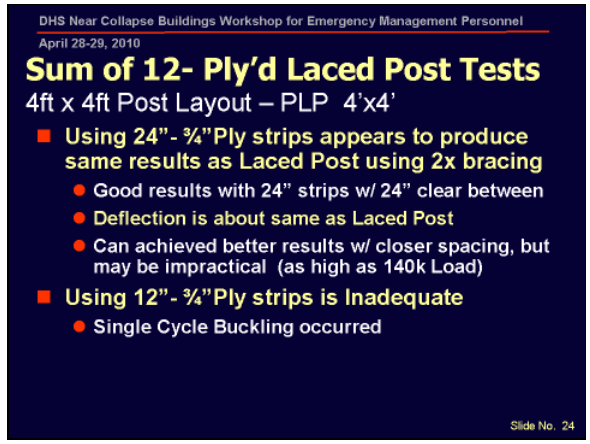
Plywood Laced Post Tests - 4'x4'
Prior to Loading
At 115K
LP-62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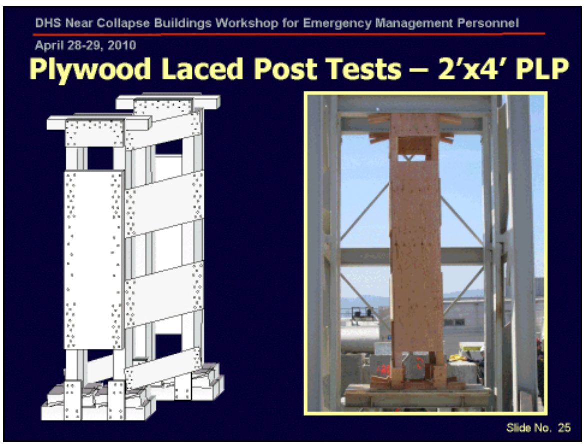
Sum of 12- Ply'd Laced Post Tests
4ft x 4ft Post Layout – PLP 4'x4'
Using 24"- ¾"Ply strips appears to produce same results as Laced Post using 2x bracing
Good results with 24" strips w/ 24" clear between
Deflection is about same as Laced Post
Can achieved better results w/ closer spacing, but may be impractical (as high as 140k Load)
Using 12"- ¾"Ply strips is Inadequate
Single Cycle Buckling occurred
Slide No. 24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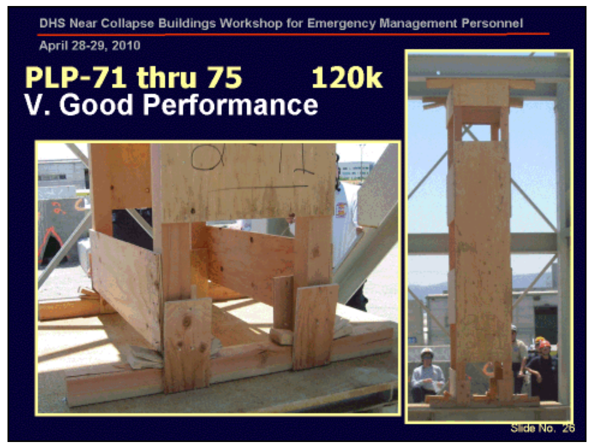
Plywood Laced Post Tests – 2'x4' PLP
Slide No. 25


DHS Near Collapse Buildings Workshop for Emergency Management Personnel
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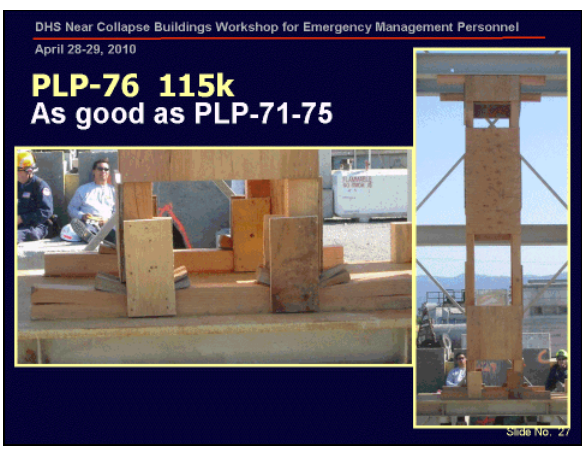
PLP-71 thru 75 120k
V. Good Performance


DHS Near Collapse Buildings Workshop for Emergency Management Personnel
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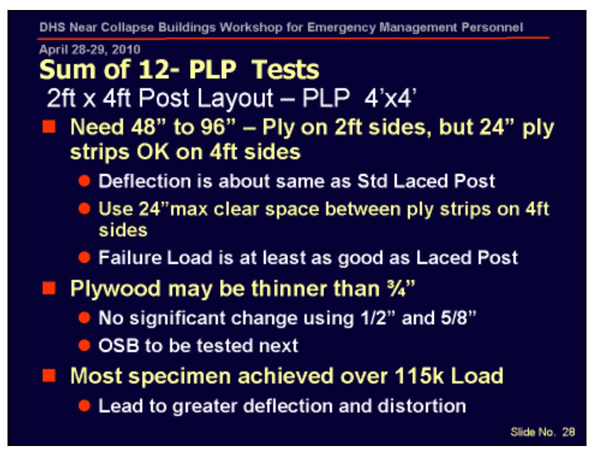
PLP-76 115k
As good as PLP-71-75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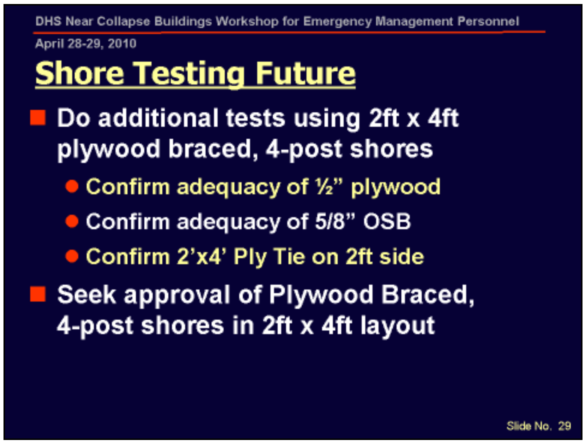
Sum of 12- PLP Tests
2ft x 4ft Post Layout – PLP 4'x4'
Need 48" to 96" – Ply on 2ft sides, but 24" ply strips OK on 4ft sides
Deflection is about same as Std Laced Post
Use 24"max clear space between ply strips on 4ft sides
Failure Load is at least as good as Laced Post
Plywood may be thinner than ¾"
No significant change using 1/2" and 5/8"
OSB to be tested next
Most specimen achieved over 115k Load
Lead to greater deflection and distortion
Slide No. 28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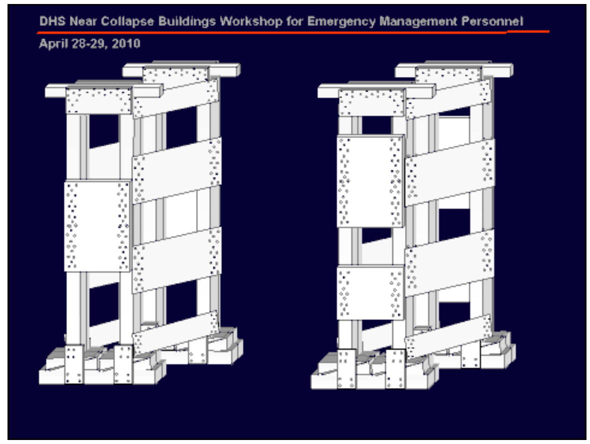
Shore Testing Future
Do additional tests using 2ft x 4ft plywood braced, 4-post shores
Confirm adequacy of ½" plywood
Confirm adequacy of 5/8" OSB
Confirm 2'x4' Ply Tie on 2ft side
Seek approval of Plywood Braced, 4-post shores in 2ft x 4ft layout
Slide No. 29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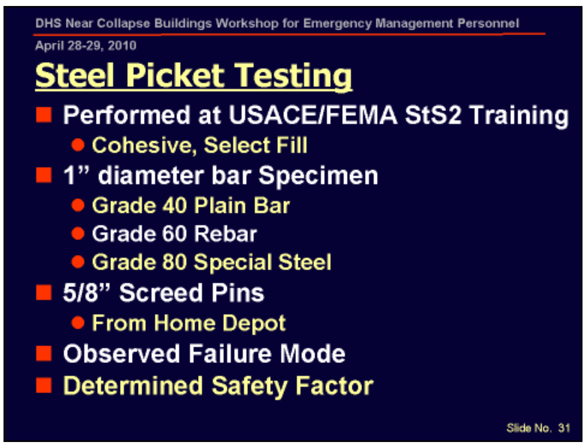
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Steel Picket Testing
Performed at USACE/FEMA StS2 Training
Cohesive, Select Fill
1" diameter bar Specimen
Grade 40 Plain Bar
Grade 60 Rebar
Grade 80 Special Steel
5/8" Screed Pins
From Home Depot
Observed Failure Mode
Determined Safety Factor
Slide No. 31


DHS Near Collapse Buildings Workshop for Emergency Management Personnel
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Picket Test Layout
Slide No. 32


DHS Near Collapse Buildings Workshop for Emergency Management Personnel
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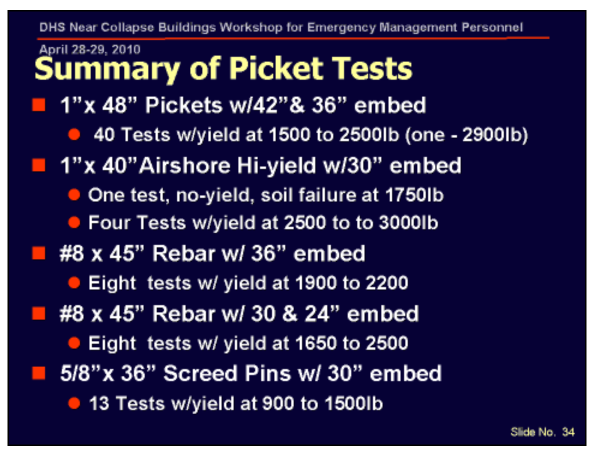
Removed Test Specimen
Location of Plastic Hinge
Slide No. 33


DHS Near Collapse Buildings Workshop for Emergency Management Personnel
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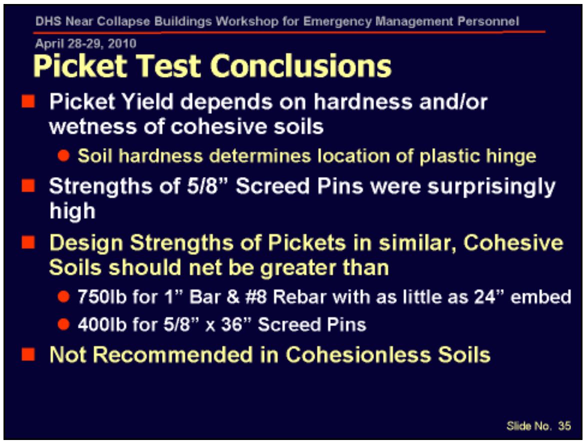
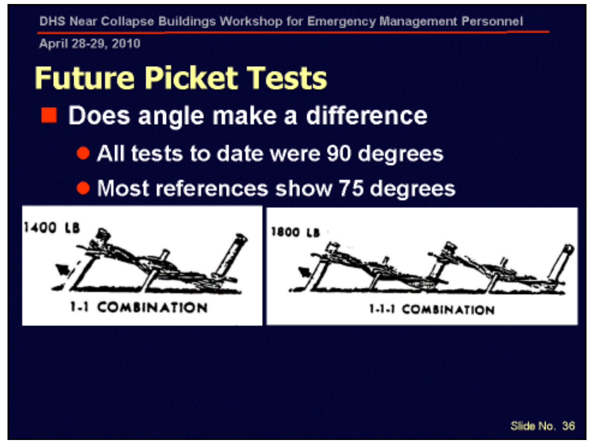
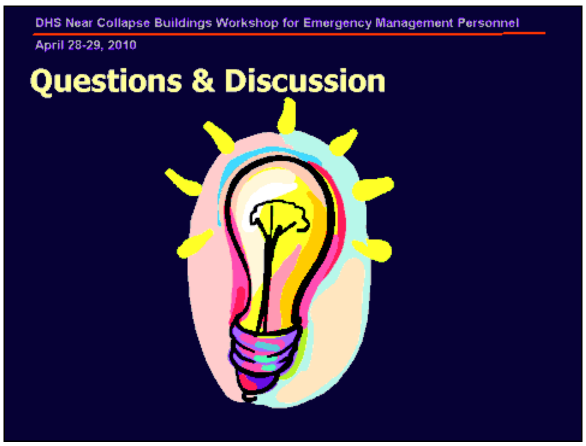
Summary of Picket Tests
1"x 48" Pickets w/42"& 36" embed
40 Tests w/yield at 1500 to 2500lb (one - 2900lb)
1"x 40"Airshore Hi-yield w/30" embed
One test, no-yield, soil failure at 1750lb
Four Tests w/yield at 2500 to to 3000lb
#8 x 45" Rebar w/ 36" embed
Eight tests w/ yield at 1900 to 2200
#8 x 45" Rebar w/ 30 & 24" embed
Eight tests w/ yield at 1650 to 2500
5/8"x 36" Screed Pins w/ 30" embed
13 Tests w/yield at 900 to 1500lb
Slide No. 34







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Shalva Marjanishvili

Dr. Marjanishvili leads Hinman's Advanced Technology practice, and is an expert in the dynamic non-linear response of structures to the effects of seismic, impact and explosive loadings. He is responsible for Hinman Consulting Engineer's analytical capabilities including progressive collapse analysis of new and existing buildings, anti-terrorist design and analysis of air-blast response of existing and new structures. He is a principal author of Hinman analysis software for evaluating structural response to explosive terrorist threats using new and innovative analysis techniques and cost effective design solutions to provide and improve reliability and robustness of structural systems against various threats and hazards, natural or manmade.

His experience includes protective anti-terrorism design, progressive collapse mitigation, vulnerability and risk assessments of numerous Federal office buildings including Federal and State courthouses, embassy structures, airline terminals including airline control towers, military installations including command and control centers, commercial building including banks, pharmaceutical and petrochemical facilities. His recent projects include the blast design of the new U.S. Embassy in Baghdad, Iraq; blast analysis and testing of multiple exterior envelope elements; and seismic peer reviews.

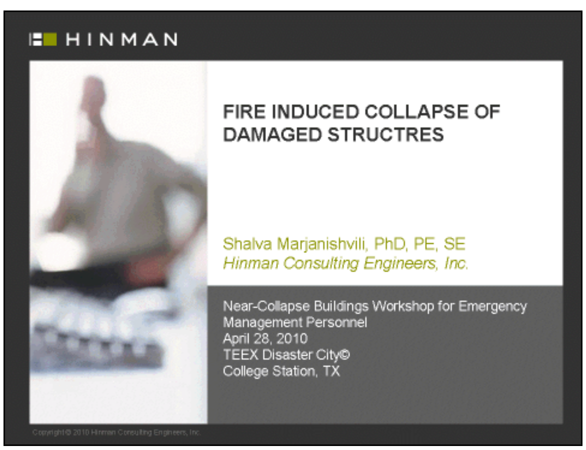
Dr. Marjanishvili has published more than 30 technical papers and has presented at national and international conferences. He is the recent author of the Masonry Section for the ASCE/SEI Blast Protection of Buildings Standards Committee as sponsored by the American Society of Civil Engineers. He has over 15 years of experience in the analysis of nonlinear response of structures. Currently, he chairs ASCE/SEI Blast Shock and Impact Committee.

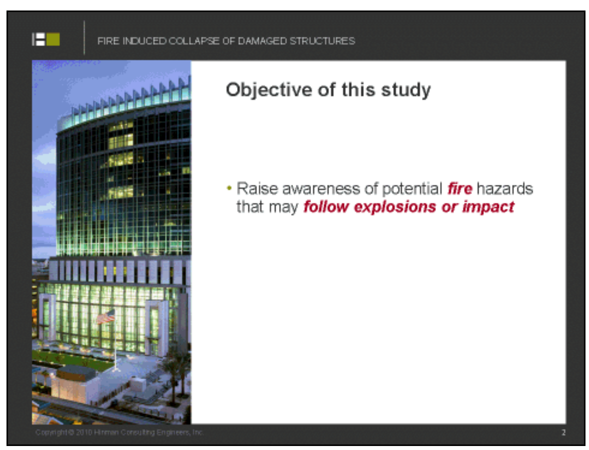
Fire-Induced Collapse of Damaged Structures

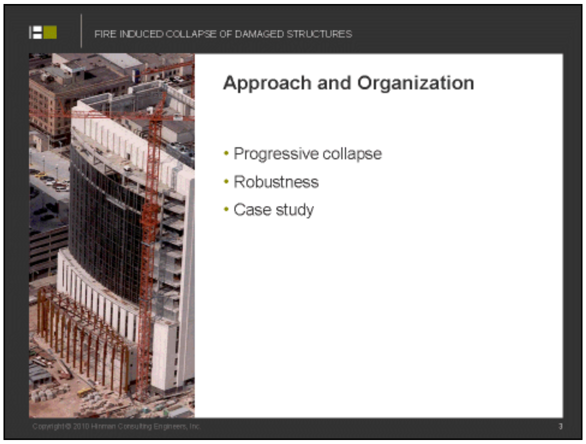
In current practice, progressive collapse analysis typically includes two types of hazards: the initial hazard that causes the localized damage (analysis referred to as specific local resistance – SLR) and the subsequent response of the structure to bridge loads across the damaged areas (analysis referred to as alternate load path – ALP). However, little detailed information is available on a third type of hazard such as fire that typically follows the initial hazard. Prolonged exposure of a damaged structure to fire could be detrimental to the short-term stability of that structure and may pose a significant threat to the safe evacuation of building occupants.

In this paper, we study the effects of fire following an explosion that causes failure of one column on the perimeter of a common steel building frame. Our approach focuses on a steel structure that is designed to satisfy new DOD (UFC 2009) guidelines and assumes that the explosion not only damages one column but also damages the fire protection applied to members in the vicinity of the explosion. Results of this study include estimates of the time to collapse initiation and a correlation between the extent of damage to the fire protection and the collapse time. The goal of this study is to raise awareness of potential fire hazards that may follow explosions and provide recommendations regarding evacuation times for occupants of damaged buildings under fire. Results of this study can be used to qualitatively determine time duration until complete collapse of the structure.

Presentation Slides







FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Approach and Organization
• Progressive collapse
• Robustness
• Case study
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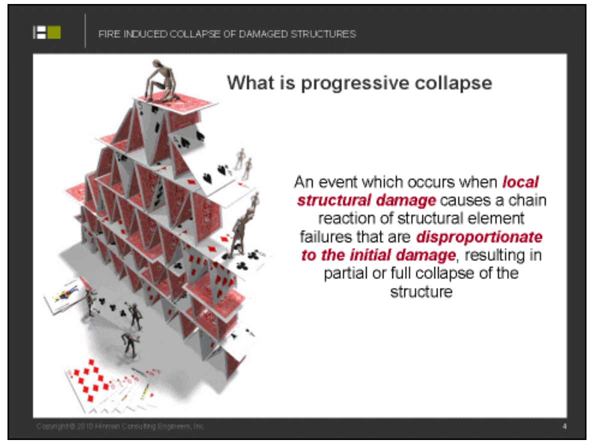
3



FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
What is progressive collapse
An event which occurs when local structural damage causes a chain reaction of structural element failures that are disproportionate to the initial damage, resulting in partial or full collapse of the structure
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FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
US State of Practice
• GSA (2003) Progressive Collapse Analysis and Design Guidelines
• UFC (2009) Design of Buildings to Resist Progressive Collapse
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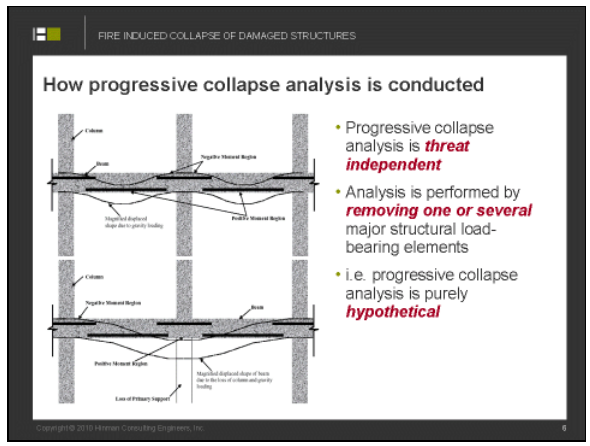

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
How progressive collapse analysis is conducted
Column
Beam
Negative Moment Region
Positive Moment Region
Loss of Primary Support
• Progressive collapse analysis is threat independent
• Analysis is performed by removing one or several major structural load-bearing elements
• i.e. progressive collapse analysis is purely hypothetical
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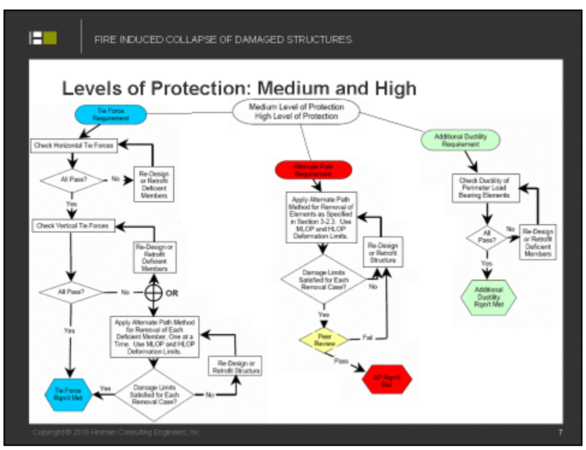

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Levels of Protection: Medium and High
Medium Level of Protection
High Level of Protection
Tie Force Requirement
Check Horizontal Tie Forces
All Pass?
No
Yes
Re-Design or Retrofit Deficient Members
Check Vertical Tie Forces
OR
Apply Alternate Path Method for Removal of Each Deficient Member, One at a Time. Use MLOP and HLOP Deformation Limits.
Damage Limits Satisfied for Each Removal Case?
Re-Design or Retrofit Structure
Tie Force Rqmt Met
Alternate Path Requirement
Apply Alternate Path Method for Removal of Elements as Specified in Section 3-2.3. Use MLOP and HLOP Deformation Limits.
Peer Review
Pass
Fail
AP Rqmt Met
Additional Ductility Requirement
Check Ductility of Perimeter Load Bearing Elements
Additional Ductility Rqmt Met
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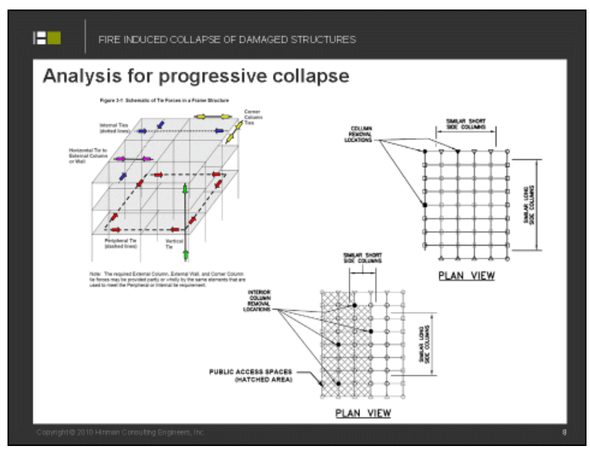

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Analysis for progressive collapse
COLUMN REMOVAL LOCATIONS
SIMILAR SHORT SIDE COLUMNS
SIMILAR LONG SIDE COLUMNS
PLAN VIEW
INTERIOR COLUMN REMOVAL LOCATIONS
PUBLIC ACCESS SPACES (HATCHED AREA)
PLAN VIEW
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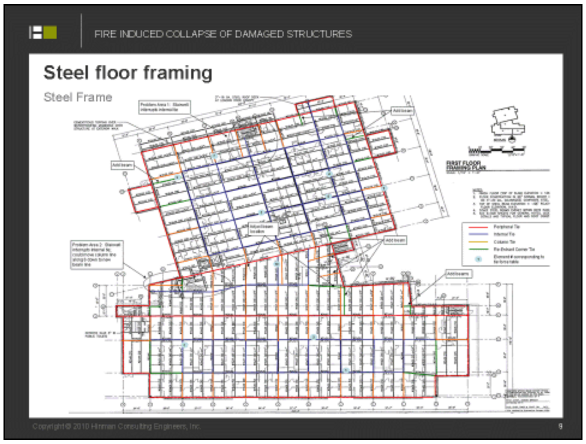

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Steel floor framing
Steel Frame
FIRST FLOOR FRAMING PLAN
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FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Typically includes two hazards
• 1. Hazard which cases the initial damage
• 2. Subsequent structural response to the initial damage (lost element/support)
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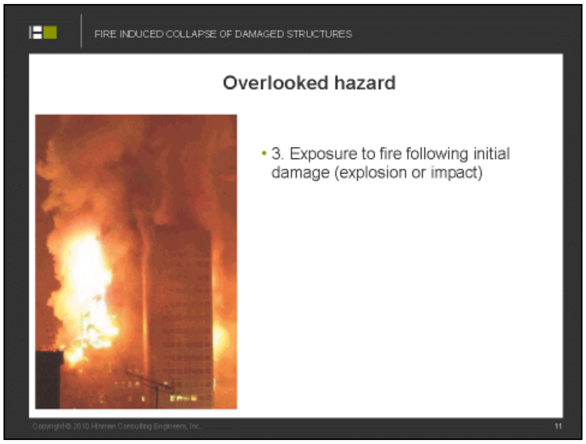

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Overlooked hazard
• 3. Exposure to fire following initial damage (explosion or impact)
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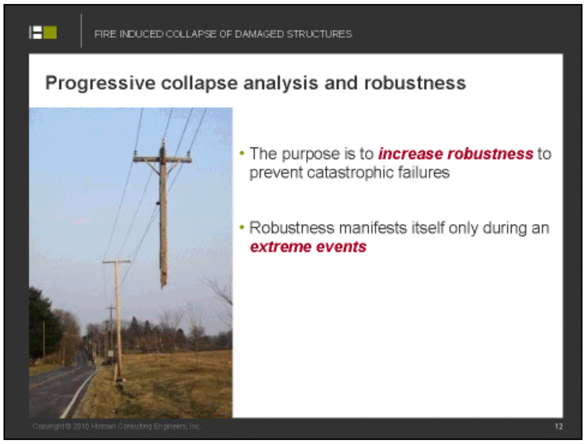

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Progressive collapse analysis and robustness
• The purpose is to increase robustness to prevent catastrophic failures
• Robustness manifests itself only during an extreme events
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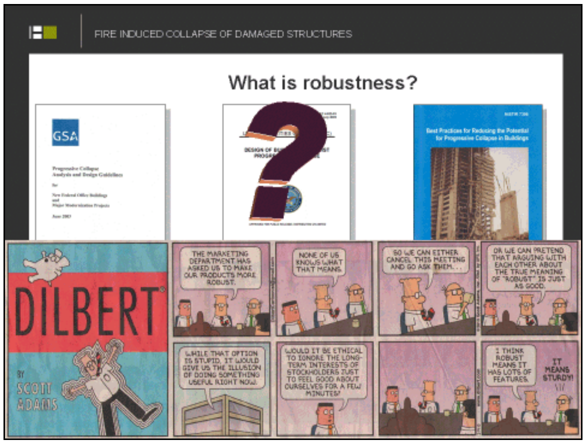
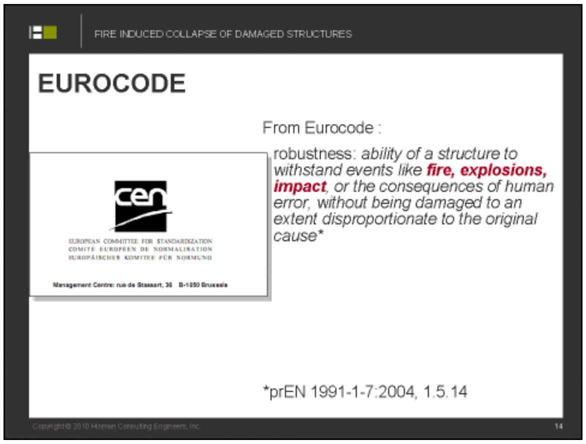


FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
What is robustness?
GSA
DILBERT
by SCOTT ADAMS
THE MARKETING DEPARTMENT HAS ASKED US TO MAKE OUR PRODUCTS MORE ROBUST.
NONE OF US KNOWS WHAT THAT MEANS.
SO WE CAN EITHER CANCEL THIS MEETING AND GO ASK THEM...
OR WE CAN PRETEND THAT ARGUING WITH EACH OTHER ABOUT THE TRUE MEANING OF "ROBUST" IS JUST AS GOOD.
WHILE THAT OPTION IS STUPID, IT WOULD GIVE US THE ILLUSION OF DOING SOMETHING USEFUL RIGHT NOW.
WOULD IT BE ETHICAL TO IGNORE THE LONG-TERM INTERESTS OF STOCKHOLDERS JUST TO FEEL GOOD ABOUT OURSELVES FOR A FEW MINUTES?
I THINK ROBUST MEANS IT HAS LOTS OF FEATURES.
IT MEANS STURDY!



FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
EUROCODE
From Eurocode :
robustness: ability of a structure to withstand events like fire, explosions, impact, or the consequences of human error, without being damaged to an extent disproportionate to the original cause*
cen
EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG
Management Centre: rue de Stassart, 36 B-1050 Brussels
*prEN 1991-1-7:2004, 1.5.14
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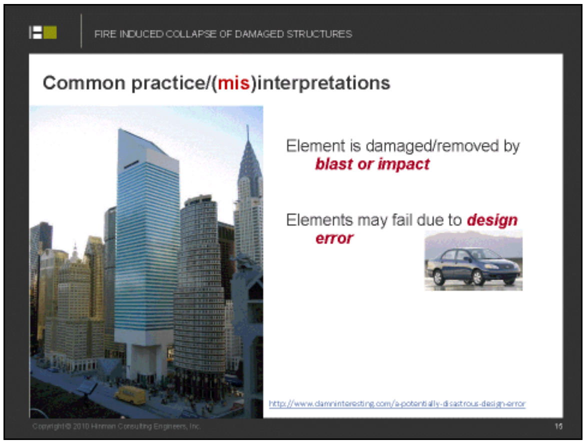

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Common practice/(mis)interpretations
Element is damaged/removed by blast or impact
Elements may fail due to design error
http://www.damninteresting.com/a-potentially-disastrous-design-error
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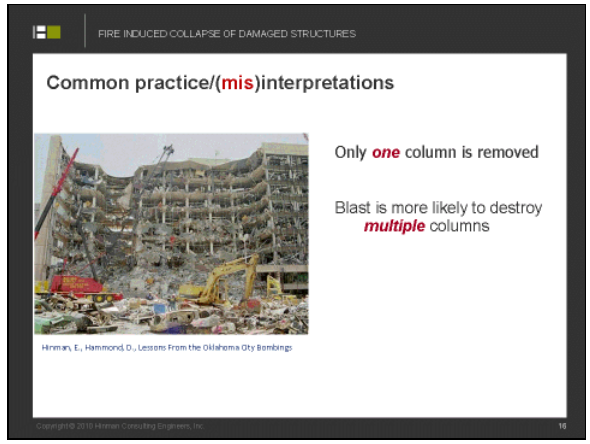

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Common practice/(mis)interpretations
Only one column is removed
Blast is more likely to destroy multiple columns
Hinman, E., Hammond, D., Lessons From the Oklahoma City Bombings
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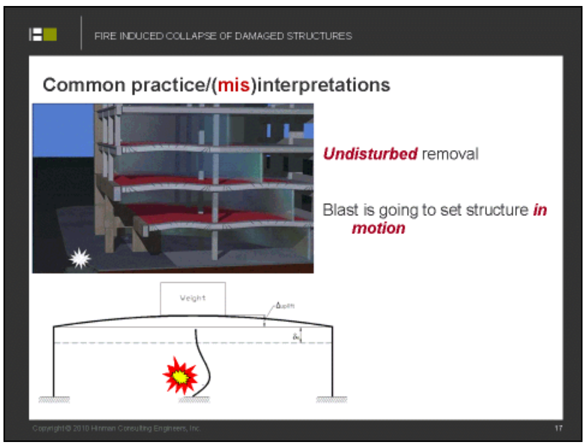

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Common practice/(mis)interpretations
Undisturbed removal
Blast is going to set structure in motion
Weight
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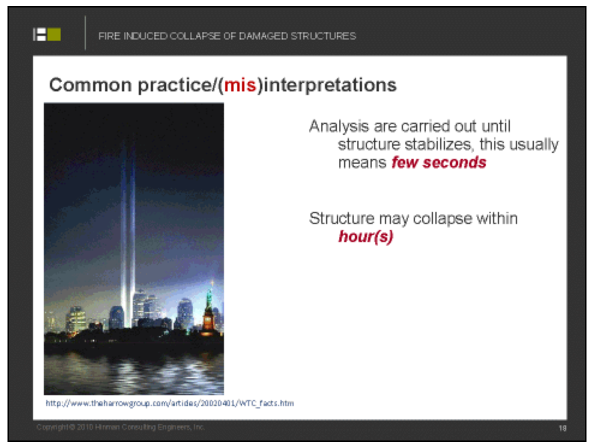
17



FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Common practice/(mis)interpretations
Analysis are carried out until structure stabilizes, this usually means few seconds
Structure may collapse within hour(s)
http://www.theharrowgroup.com/articles/20020401/WTC_facts.htm
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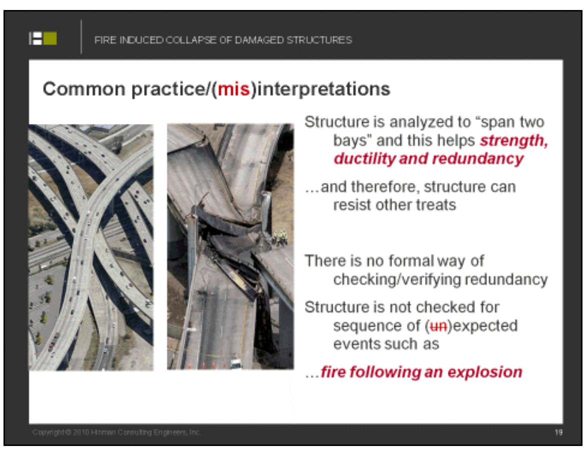

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Common practice/(mis)interpretations
Structure is analyzed to "span two bays" and this helps strength, ductility and redundancy
…and therefore, structure can resist other treats
There is no formal way of checking/verifying redundancy
Structure is not checked for sequence of (un)expected events such as
…fire following an explosion
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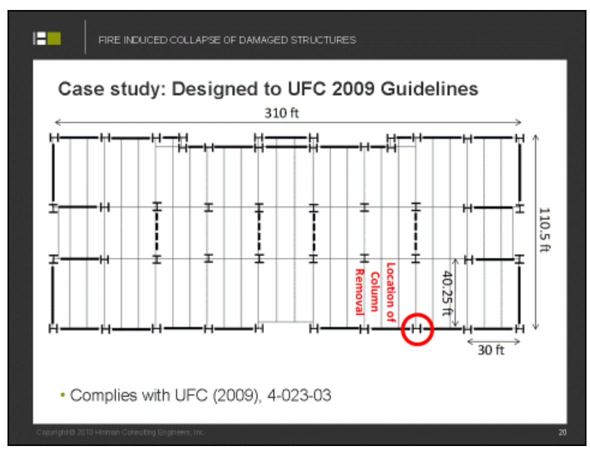

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES
Case study: Designed to UFC 2009 Guidelines
310 ft
110.5 ft
40.25 ft
30 ft
Location of Column Removal
• Complies with UFC (2009), 4-023-03
Copyright © 2010 Hinman Consulting Engineers, Inc.
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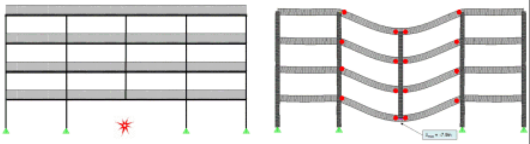
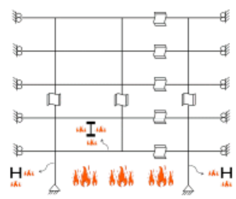
FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES

Case study: Progressive collapse analysis model



FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES

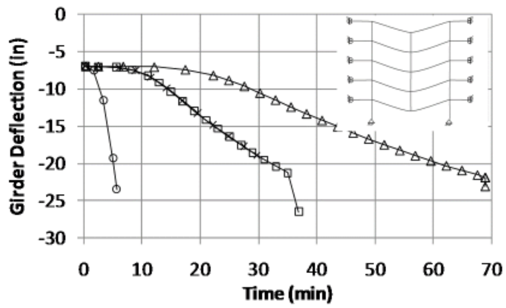
Case study: Fire analysis model



- CASE 1: Both girder & column unprotected
- CASE 2: Girder 1hr & column unprotected
- CASE 3: Both girder & column 1hr protected
- CASE4: Girder 2hrs & column 1hr

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES

Case study: Girder response

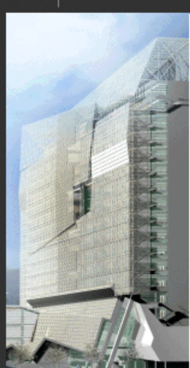


FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES

Case study: Results

Fire Protection		**Time to Failure**
Girder	**Column**	
0 hr	**0 hr**	**5 min**
1 hr	**0 hr**	**29 min**
1 hr	**1 hr**	**36 min**
2 hr	**1 hr**	**1 hr 8 min**

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES

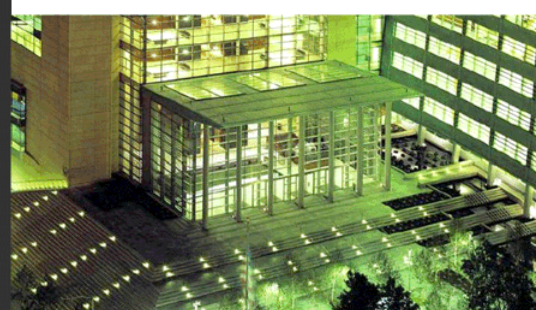


Conclusions and Recommendations

- ***We conclude:***
  - When dealing with low probability - high consequence events all feasible threats should be considered
- ***We Recommend:***
  - Include fire effects into progressive collapse design guidelines

FIRE INDUCED COLLAPSE OF DAMAGED STRUCTURES

Discussion and Questions



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Holly Stone

Hollice Stone, PE, President of Stone Security Engineering, is an experienced Security Engineer, with 18 years of engineering, blast, antiterrorism and emergency response experience. She has devoted her career to helping protect people, buildings, campuses, and critical infrastructure from terrorism. Stone has been instrumental in criteria development, research, and educational initiatives in both the engineering and emergency response communities. Accomplishments include anti-terrorism and security engineering design and assessments of new and existing facilities for the U.S. Departments of State, Justice, Homeland Security, and Defense, National Universities, chemical plants, oil refineries, Fortune 500 companies, and international non-governmental organizations.

Ms. Stone has also been instrumental in bridging the gap between security engineering and more traditional life-safety considerations through her work with FEMA, developing training simulators for widespread structural collapse scenarios, presenting first responder classes on explosion hazards, working with the Fire Department of the City of New York in their development of Emergency Action Plan Director certification examinations in support of Local Law 26, acting as a member of the elite cadre of instructors for the FEMA/Army Corps of Engineers Advanced Structures Specialist course for rescue engineers and teaching at the Department of Homeland Security's Incident Response to Terrorist Bombings course in New Mexico.

An Approach to Correlating Air-Blast Analysis Results and Post-IED Structural Residual Capacity
Arturo Montalva

Building design under catastrophic loads, including air-blast, is a well studied field. However, the recognized response limits used in design include very limited information regarding the post-event capacity of the structure and therefore cannot, at this time, be used to provide information to rescue teams and first responders regarding building stability during rescue operations.

In air-blast design, the most common design procedure is nonlinear, dynamic, single-degree-of-freedom analysis of structural elements. This analysis type is able to capture the complexity of the axial/bending response of a structural member while maintaining computational efficiency. This analysis procedure evaluates the values of the peak dynamic ductility and structural element support rotations against limits that are based on the required level of protection of the building and the importance of the structural/architectural element evaluated.

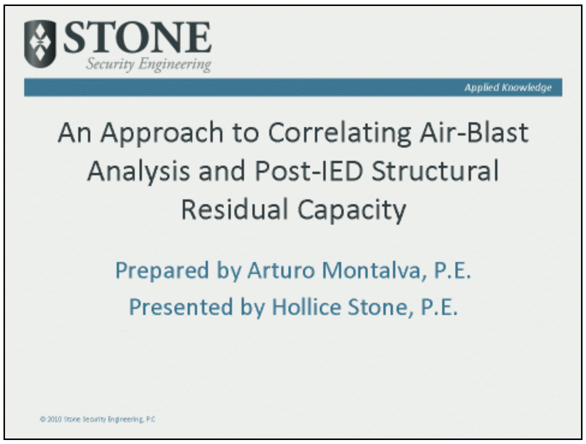
Unfortunately, even though these response limits are adequate and convenient for building design, they have very limited meaning for post-event building evaluation because:

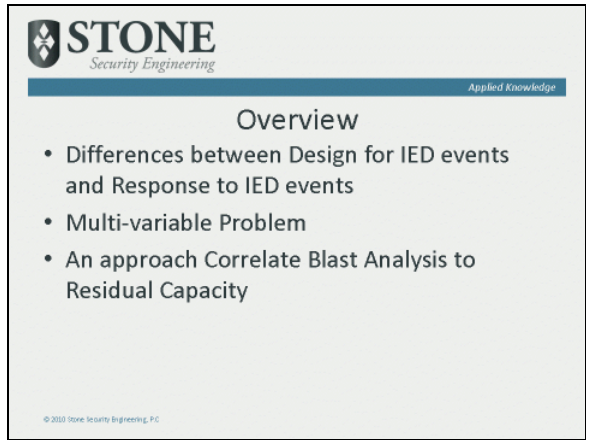
- They are based on the peak dynamic response of the structural/architectural element and not on the permanent response of the member; and

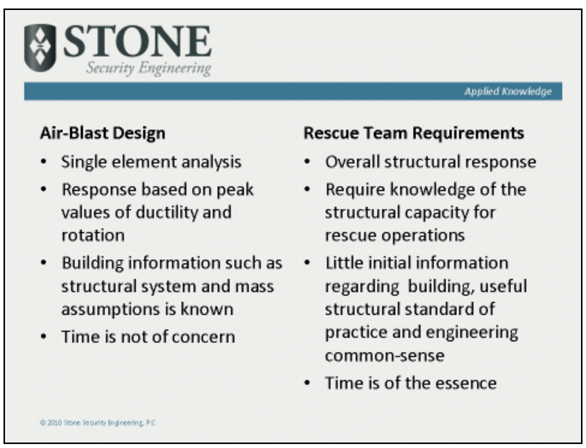
- They do not adequately address the post event residual capacity of each structural element, and therefore the post-event ability of the structure to continue to support loads.

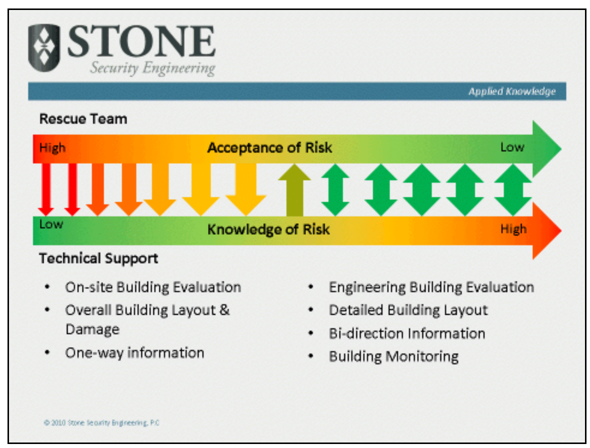
First responders and rescue teams must be able to understand not only the structural damage that has occurred, but the remaining structural capacity of the building systems. In this presentation we discuss a possible approach to correlate single-degree-of-freedom air-blast.

Presentation Slides









STONE Security Engineering
Applied Knowledge

Levels of Information

I On-site evaluation, observation and survey
Additional information developed by additional responders

II Drawings

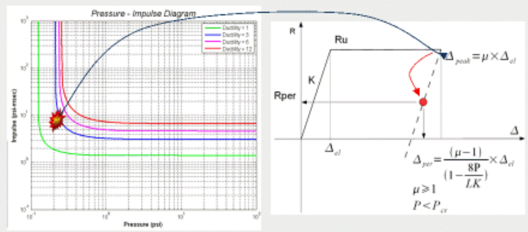
III Create database of primary targets for faster evaluation and training

IV BIM

The accuracy of the assumption defines the precision of the predictions – Important to update model real-time

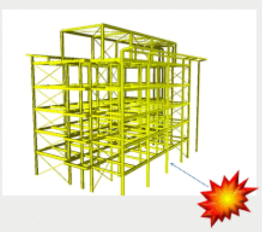
STONE Security Engineering
Applied Knowledge

SDoF Dynamic Response **Permanent Deflection**



STONE Security Engineering
Applied Knowledge

Post-IED Building Evaluation



- Estimate threat size based on vehicle/package and crater size
- Required information of structural system and mass (can make assumptions)
- Perform SDoF Analysis – Create PI Diagrams
- Based on threat, obtain Permanent Deflection
- From Permanent Deflection define remaining capacity
- Identify/Classify Safe areas of the building

STONE Security Engineering
Applied Knowledge

What Does This Tell Us?

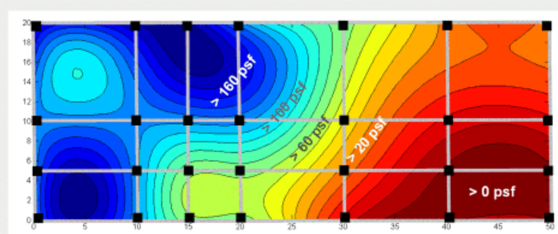
- Flexural Members (beams or slabs): understanding of the remaining connection capacity
- Compression Members (columns): information of the additional compression capacity
- Debris Predictions: based on types of damage can be introduced in the model based on the expected permanent deflection
- Available research by FEMA on seismic element and connection resistance functions can be used to predict remaining capacity with multiple failure mechanism
- **Remaining load carrying capacity areas (useful psf) and collapsed or near collapse areas**

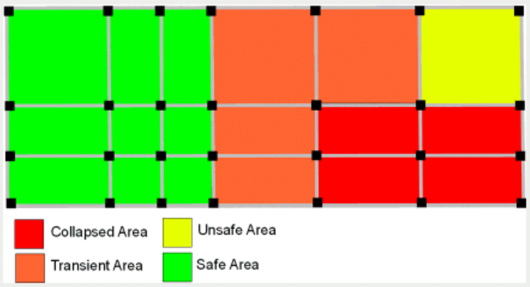
STONE Security Engineering
Applied Knowledge

Useful psf Can Be Translated Into…

- Collapsed Areas
- Damaged Areas
- Transient Areas
- Permanent Operation Areas
- **Where can I stay and how safe is it? Where can I store my equipment? And where can I use my equipment?**

STONE Security Engineering
Applied Knowledge





Real-time Feedback

- Model must be upgradable with additional information and on-site observations
- Input data can be rated and probabilistic scale can be included to the building evaluation
- Simplified modeling speed computation and provide a real-time safety data to rescue teams
- BIM can include rescue information

Future Research/Steps

- Develop tactical sheet (including research and database development)
- Develop code
- Develop user and post-processing interface
- Local area database of buildings
- Integrate into BIM
- Outreach and training

Conclusions

- Proposed simplified model to evaluate post IED event capacity of the building - Multiple failure mechanism can be used in the model
- Blast modeling techniques are used to evaluate building and floor mapping is generated to identify the safety of different parts of the building
- Real-time update of the model is required as additional information is collected
- Implementation of BIM techniques for rescue operations can provide faster modeling and training support

Thanks for your attention

Arturo Montalva – Arturo@StoneSecurityEngineering.com
Hollice Stone – Holly@StoneSecurityEngineering.com

http://www.StoneSecurityEngineering.com

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Brian Beadnell

Brian Beadnell has served in the emergency response, preparedness and planning field for almost 26 years. His extensive experience and expertise includes instructional, operational, fiscal, planning and logistics management, in and with many local, State, and Federal agencies.

Currently Mr. Beadnell consults and continues to instruct, lecture, and work on developmental planning, reach and rescue, hazardous materials, CBRNE and operational logistics nationally and internationally, which have included The State Department for the Jamaican Fire Service, Office of The Deputy Prime Minister at the National Fire Service College, Police National CBRN Centre, and The London Fire Brigade for the United Kingdom. He is a National Cadre Adjunct Instructor at Texas A&M University for national and international Urban Search & Rescue programs and courses. He has provided training and services for a variety of Fortune 500 companies. He has authored several articles and co-authored the National Logistics Specialist course for DHS/FEMA

His national incident management assignments include The California Northridge Earthquake, The California Flood/Water Response, The Oklahoma City Bombing, The Pentagon Attack, World Trade Center Attack, & Hurricane Katrina / Rita, in addition to multiple responses of National consequence across the county.

A Possible Approach to Developing IED Rapid Response Support Packages

The resources that are intended to be utilized and/or are necessary for effective operations to mitigate an incident should be configured in a rapid deployment equipment cache package and pre-staged at strategic locations or pre-identified in locations throughout the county. These resources include personnel that possess rapid assessment and stabilization knowledge skills, abilities, and techniques to correctly identify high leverage mitigation activities. These packages would be resources that assist with the process of rapid assessment techniques for determining building instability/stability.

These IED rapid response support packages that support the initial evaluation and mitigation process of an IED evaluation team should be standardized and typed in the same format as other National or Regional Response and Support assessments such as Urban Search & Rescue Teams (US&R), Disaster Medical Assistant Teams (DMAT), Pre-positioned Equipment Program (PEP).

Each response package should be modular in design to be either stand alone or componentized so that it could be added into one of the Federal or regional responses assets on an as-needed bases.

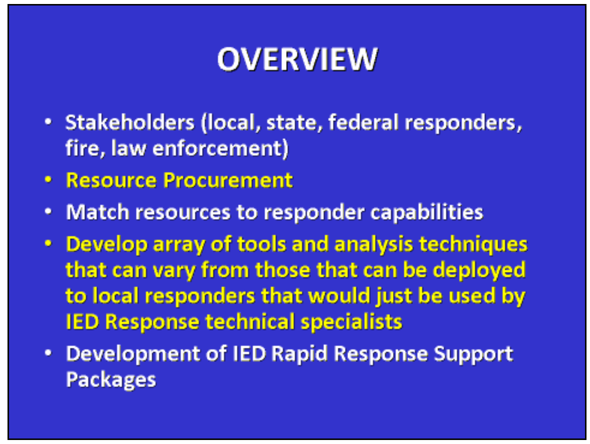
The value to this sort of design is that it can be rapidly deployed to an incident so that valuable time is not expended on locating resources and personnel to fit the need of the incident and costly procurement of equipment at the time of the incident. Equipment evaluation comparisons of these resources can be performed at Texas A&M to provide the needed testing and evaluation environment that Disaster City has to offer and the necessary skilled professionals in the variety of needed abilities.

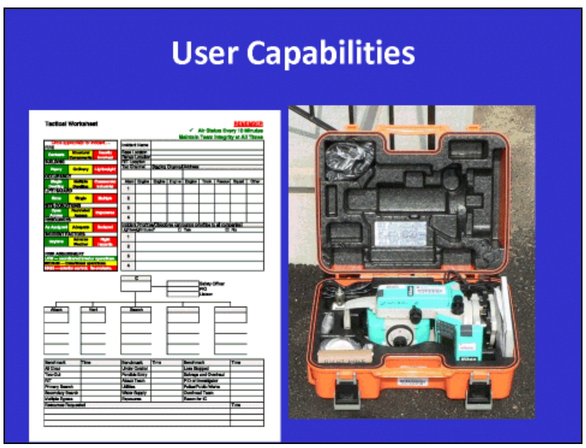
SESSION 3

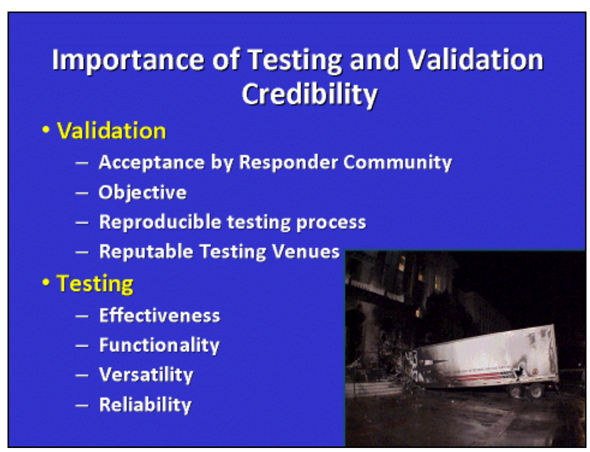
DECISION THRESHOLDS

This presentation also discusses considerations that should be addressed when developing new tools for first responders and US&R teams.

Presentation Slides







Decision Making – Procurement

- Depends on Frame of Reference
- Tested/Validated
- Cost/Cube/Weight
- Performance/Capability
- Standardized/Interoperable
- Service/Warranty/Mfg support

Decision Making – Point of Use

- Adequate resources
- Sustainability of support
- Time
- Capacities
- Capability
- Knowledge of Operation
- Effectiveness

How to Organize Tools Once Developed

- Typing System (National Typing Initiative)
  - Kind/Type is Known
  - Standardized/Reproducible
  - Accessible
  - AEL/SEL
- For Post-IED Packages
  - Capabilities (scalable)
  - Kit Concept/Consumables
  - Packaging/Storage
  - Deployability

The Most Important Advancement in Structural Collapse Response in Last 20 Years

- US&R Program
  - Advancements in response capabilities
  - Threats/Hazards
  - Developing, vetting and disseminating new approaches
  - Tool development
  - Training
  - Regionalization/expansion

Post-IED Rapid Response Teams

Can be developed to integrate or augment US&R teams or other national assets

- Multiple disciplines (evidentiary gathering & preservation, bomb techs, engineers, rescue/medical/logistics specialists,)
- Cache of equipment (standardized and complementary to US&R or other resources)

QUESTIONS???

Thank You

Brian Beadnell
925-207-8115 cell
bvbeadnell@aol.com

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SESSION 3

DECISION THRESHOLDS

Peter Keating

Dr. Pete Keating is an Associate Professor in the Civil Engineering Department and an Associate Research Engineer with the Texas Transportation Institute, both at Texas A&M University, College Station, Texas. He is also Director of the Structural and Materials Testing Laboratory. He received B.S., B.A. (architecture), M.S. and Ph.D. degrees from Lehigh University in Bethlehem, PA. He teaches both graduate and undergraduate courses in structural engineering and performs research primarily in the area of structural fatigue. Other research has involved the development of fatigue repair procedures for steel highway bridges, the study of diaphragm cross frame influence on the fatigue and load distribution behavior of highway bridges, and the fatigue behavior of damaged and dented petroleum pipelines (for the Office of Pipeline Safety, U.S. DOT). He has also been a Structures Specialist with Texas Task Force One since 2000. He is the chairperson of FEMA's US&R Structures Subcommittee as well as a member on FEMA's Incident Support Team (Red). He is a registered Professional Engineer in the State of Texas.

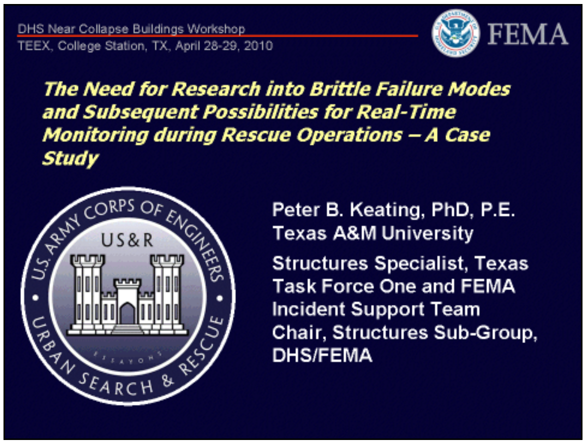
The Need for Research into Brittle Failure Modes and Subsequent Possibilities for Real-Time Monitoring during Rescue Operations – A Case Study

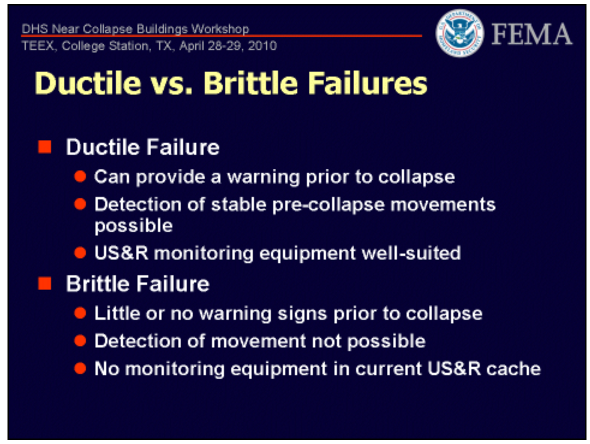
This presentation discusses the need for research into failure mechanisms of building elements subjected to a sustained overload condition. Once we have greater understanding of the failure mechanisms, we can make informed decisions as to the type of sensors that would be most useful in different post-blast rescue situations. The presentation uses the case study involving a secondary collapse of a precast parking structure during rescue operations.

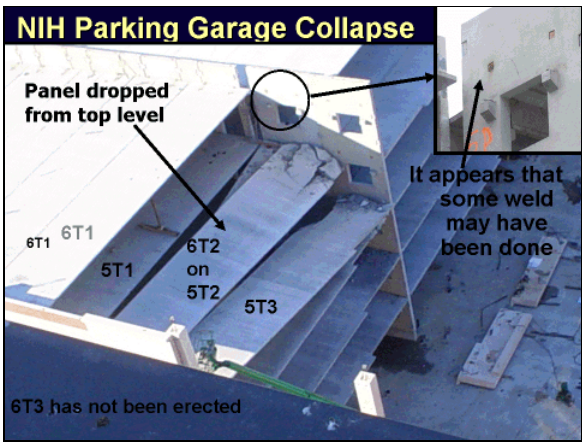
The collapse of a pre-cast component required a US&R response to extricate a victim. Immediately following the removal of the victim, a secondary collapse occurred that was sudden (brittle) and without warning. Fortunately, there were no additional victims. Our preliminary research into the failure mode indicates that the failure occurred due to a sustained overload condition on a lightly reinforced concrete corbel.

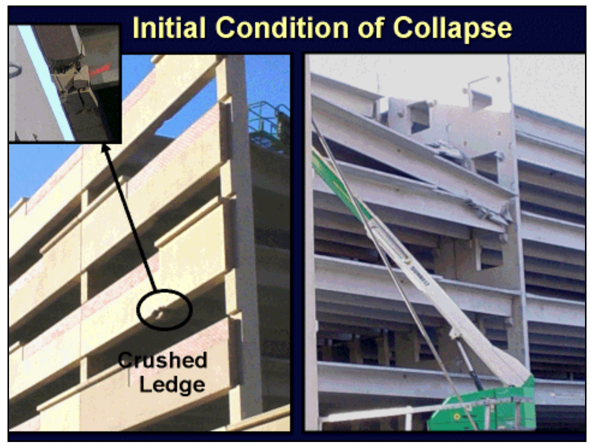
This secondary collapse illustrates the inadequacies of our current understanding of failure modes and thus the inadequacies of our US&R monitoring systems for providing advanced warning for this type of failure. A discussion on the current and future needs for research into brittle structures failures and monitoring of these structures during rescue operations is provided.

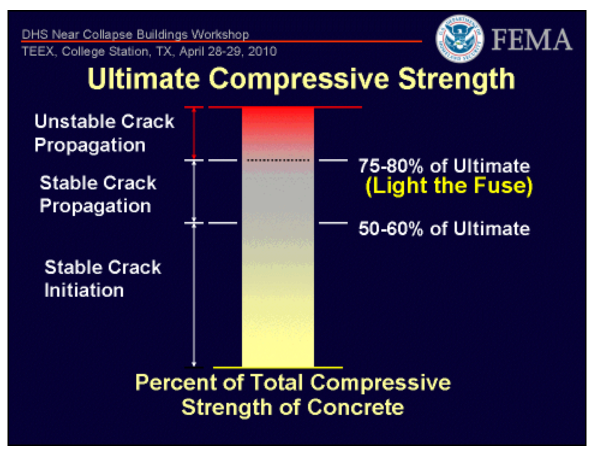
Presentation Slides



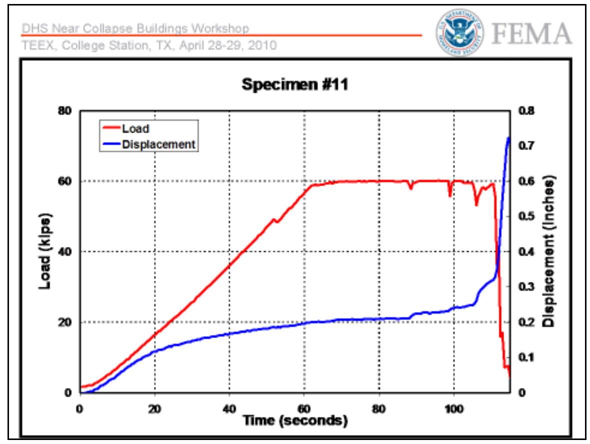




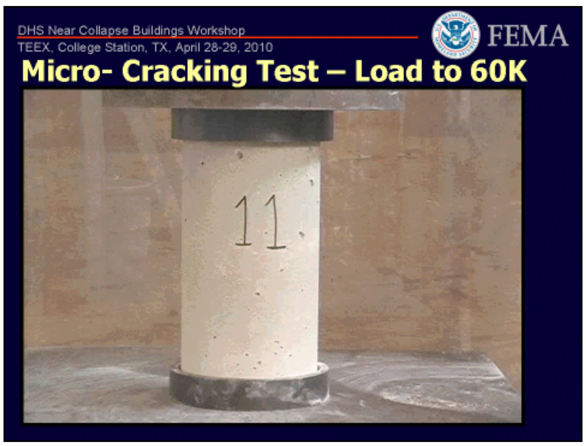




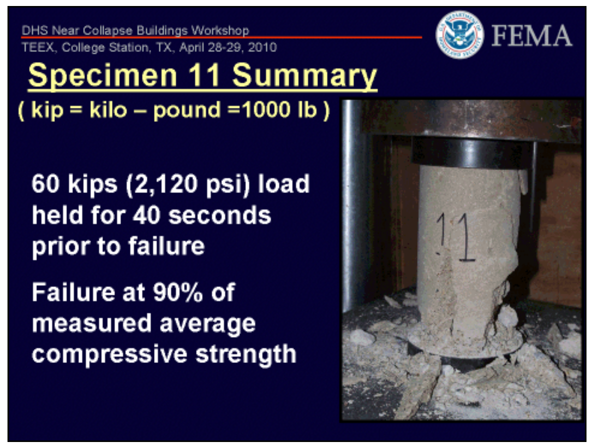
DHS Near Collapse Buildings Workshop
TEEX, College Station, TX, April 28-29, 2010
FEMA
Standard Testing for Compressive Strength
(ASTM C 39)
6" Diameter
12" High
28-Day Strength
Load to 90-95% of ultimate strength and hold
MTS



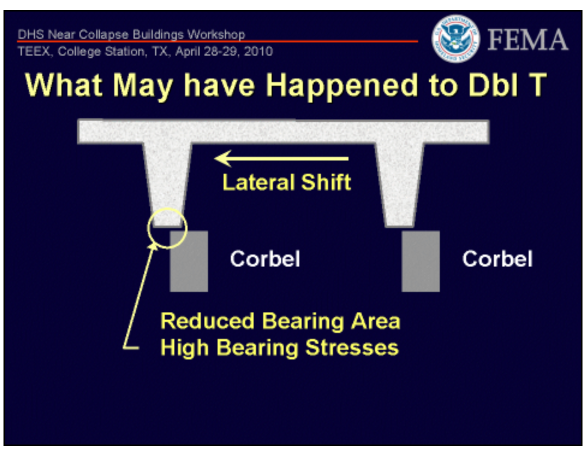
DHS Near Collapse Buildings Workshop
TEEX, College Station, TX, April 28-29, 2010
FEMA
Specimen #11
Load
Displacement
Load (kips)
Displacement (inches)
Time (seconds)
0
20
40
60
80
100
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8



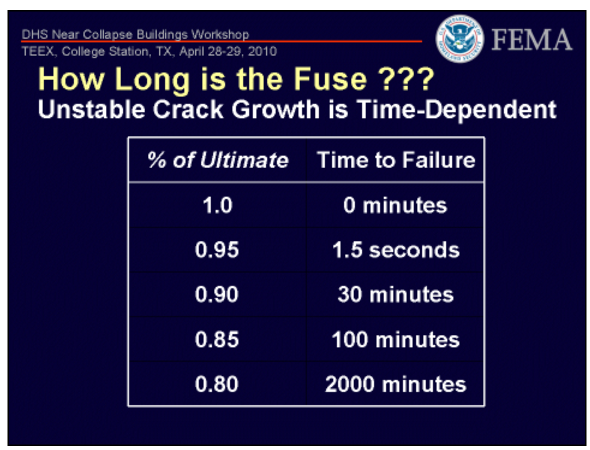
DHS Near Collapse Buildings Workshop
TEEX, College Station, TX, April 28-29, 2010
FEMA
Micro- Cracking Test – Load to 60K
11



DHS Near Collapse Buildings Workshop
TEEX, College Station, TX, April 28-29, 2010
FEMA
Specimen 11 Summary
(kip = kilo – pound =1000 lb)
60 kips (2,120 psi) load held for 40 seconds prior to failure
Failure at 90% of measured average compressive strength
11



DHS Near Collapse Buildings Workshop
TEEX, College Station, TX, April 28-29, 2010
FEMA
What May have Happened to Dbl T
Lateral Shift
Corbel
Corbel
Reduced Bearing Area
High Bearing Stresses



DHS Near Collapse Buildings Workshop
TEEX, College Station, TX, April 28-29, 2010
FEMA
How Long is the Fuse ???
Unstable Crack Growth is Time-Dependent
% of Ultimate | Time to Failure
1.0 | 0 minutes
0.95 | 1.5 seconds
0.90 | 30 minutes
0.85 | 100 minutes
0.80 | 2000 minutes

• • •

Bil Hawkins

Bil has been a Structures Specialist in the FEMA Urban Search and Rescue system since 2000 and is currently a Structure Specialist with CO-TF1 (Colorado) and member of Park County Wilderness Search and Rescue. He is SPRAT Level III and IRATA Level II certified as a rope access technician leading teams on complex bridge and building inspections. He is the Director of Structural Engineering and a Principal of Knott Laboratory, a nationally recognized forensic engineering firm located in Denver, Colorado.

Bil was on the first team of USACE engineers to deploy to the Haiti 2010 earthquake and was designated the Incident Commander by the UN Fire Chief for the Hotel Montana recovery operation, extracting 70 souls from the concrete pancake collapse. Bil was also on the first team of USACE engineers to deploy Iraq at the onset of Operation Iraqi Freedom and spent 8-months in theater including 10-days as an advisor recovering dead students from the concrete pancake collapse at the Celtiksuyu dormitory school during the Bingol, Turkey earthquake in May 2003.

Bil was the team leader for Kenyon International during a subsequent trip to Haiti to recover the body of a 5-year old girl from New Zealand. He is currently in discussions with Kenyon International to assist their highly technical team of recovery specialists in surgically deconstructing structures in order to extract bodies with respect and dignity. He is a Marine Corps veteran who lives by the Chinese term "Gung Ho" meaning a willingness to tackle any task with total commitment.

When Rescue Turns to Recovery

This presentation goes through the different mindsets of how to shore partially collapsed structures when the reward of rescuing live victims is no longer viable. Factors of safety become greater while the acceptable risk becomes far less. Often heavy equipment or controlled blasting is used to bring down the structure in order to retrieve the victims, though these methods are not always desired by the grieving family members.

Mr. Hawkins provides two case studies where recovery of an entombed victim was done in a surgical manner utilizing shoring and/or alternative mitigation techniques to reduce the exposure of the rescuers. One case study is a man who had fallen into a large active sink hole beneath the basement level of a wood frame three-story structure. The other is a case of a 5-year-old girl entombed beneath a five-story partially collapsed concrete post-and-beam structure that had been damaged as a result of the 2010 Haiti earthquake. In each case, the victims were recovered with respect and dignity without damaging the bodies or injuring the rescuers.

Mr. Hawkins' multi-media PowerPoint presentation includes photographs and written descriptions of the planning, execution and contributing factors involved with making these two successful recoveries using an almost surgical-like method of controlled demolition utilizing shoring methods far exceeding typical rescue methods. Each recovery utilized typical first responder Incident Command Structure systems with extraction teams made up of first responders and technical experts.

Presentation Slides

KNOTT LABORATORY, LLC — KENYON

When Rescue Turns to Recovery

Decision Thresholds and Risk Management
DHS Near Collapse Workshop
April 28, 2010

Bil G. Hawkins, P.E., CFEI, CFII
Director, Civil-Structural Engineering
Knott Laboratory, LLC
7185 South Tucson Way • Centennial, CO 80112-3987 • p 303.925.1900 • f 303.925.1901
www.knottlab.com

Lesson Plan

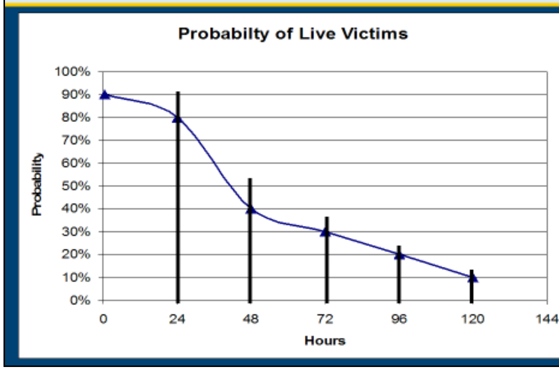
- Rescue & Recovery
  - Decision Threshold
  - Risk Management
- Case Studies

Rescue – Decision Threshold

- What is the Purpose or Goal ?
- Triage & Stabilize
  - Victims
  - Structures
  - Hazards

CREATE NO NEW VICTIMS

Decision – Victims

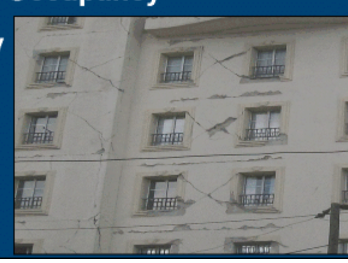


Decision – Victims

- Live Victims ?
  - 3 Minutes Without Air
  - 3 Hours Without Shelter
  - 3 Days Without Water
  - 3 Weeks Without Food

Decision – Structures

- Ductile vs Brittle
- High vs Low Occupancy
- Accessibility
- Stability
- Quality

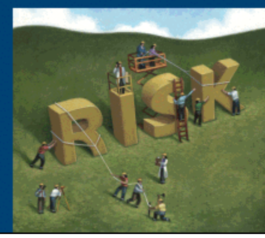


Decision – Hazards

- Falls & Trips
- Collapse
- Hazardous Materials
- Monitor/Mitigate/Avoid

Risk Management

- Likelihood of Live Victims
- Likelihood of Collapse or Failure
- Safety Factor
- Minimize Hazards
- Risk vs Reward



Risk Management

- 210 Trained Specialists (3 Deep)
  - Search – Locate Victims
  - Rescue – Extricate Victims
  - Technical – Planning & Engineering
  - Medical

Rescue vs. Recovery

WHY DO RECOVERY ?

Why Do Recovery ?

Why Do Recovery ?

- Innocent Victims
- Loved Ones
- Brothers & Sisters Serving

"Discarded with the Debris…"

Decisions in Recovery

- Who Are the Best Qualified
- What Changes From Rescue
- What Doesn't Change…
- What is Success ?

CREATE NO NEW VICTIMS

CREATE NO NEW VICTIMS

Decision – Best Qualified

- Trained Rescue Teams
- Construction Types
- DoD
- Coroners/Morticians
- Anthropologists

Decision – Change From Rescue

- What Doesn't Change… ?
- Triage & Stabilize
  - Victims
  - Structures
  - Hazards

Decision – Change from Rescue

- You Have TIME…

0 24 48 72 96 120

Hours

Plan, Plan and Plan Again…

Decision – Change from Rescue

- Equipment Methods
- Search & Extraction Techniques
- Trading in the Dental Pick

Decision – Change from Rescue

Decision – Recovery

- What Does Success Look Like ?
- Bodies
  - Located
  - Extracted in Tact
  - Identified
  - Returned to Loved Ones

Risk Management – Recovery

- Plan – You Have Time
- Mitigate
- Higher Factors of Safety
- Less Acceptable Risk

Risk Management – Recovery

- Resources Available
  - Type
  - Quantity
  - Cost
- How Dangerous is Operation
- How Difficult to Extract

Recovery – Summary

- Time…
  - Plan…Mitigate…Plan Again
- Decision Thresholds
  - Hazards…Resources…Time…
- Risk
  - Acceptable Levels

Case Studies

- Branch Mine Explosion
- Alta Mine Collapse
- Haiti Earthquake

Big Branch Mine

- Four Missing Right Inside Shaft
- Rescue Team in Harms Way

Alta Mine Collapse

- Sinkhole Over Abandoned Mines
- Single Victim at Edge of Hole
- Two Story Wood House Above
- Shifting Soils/Confined Space
- Underground Gases

Hotel Karibe – Haiti

- Five Story Concrete Post & Beam
- Father, 4 & 2 Year Old Daughters

Hotel Karibe

Hotel Karibe

Hotel Karibe

Hotel Karibe


Hotel Karibe

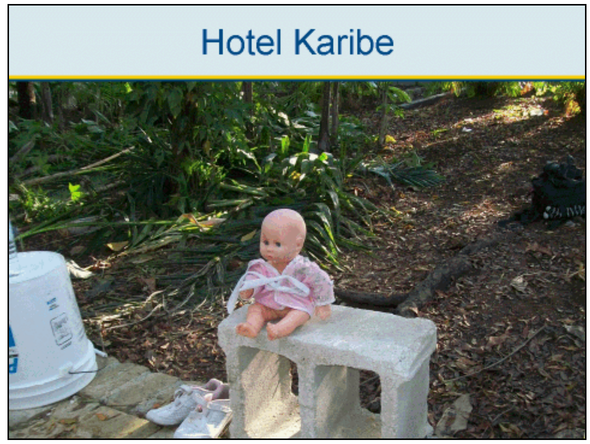

Hotel Karibe

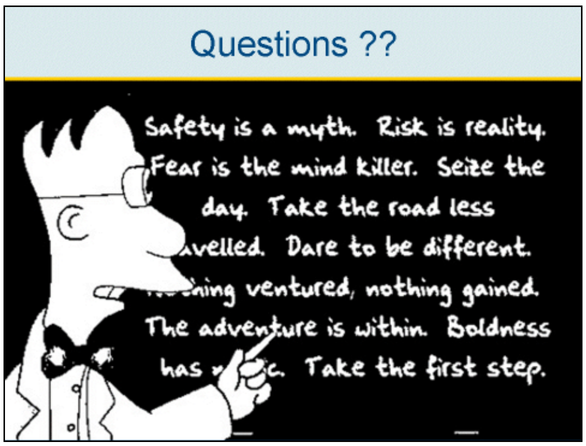

Hotel Karibe


Hotel Karibe


Hotel Karibe


Hotel Karibe
21/02/2010
21/02/2010





• • •

Mohammed Ettouney

A bio of Dr. Ettouney can be found on page 7.

Risk-Based Rapid Visual Screening Tools for Near-Collapse Buildings

This presentation describes some of the basics of risk-based decision tools that objectively evaluate risks involving potential instability and failures of near-collapse buildings that confront first responders and other decision makers after an IED attack.

Presentation Slides

Risk-Based Rapid Visual Screening Tools for Near-Collapse Buildings

Mohammed M. Ettouney, PE, PhD, MBA, F.AEI
Principal, Weidlinger Associates, NYC, NY

28th April, 2010

Outline

- Risk Management: Types of Risk
- Components of Risk Assessment
- Risk and Decision-Making
- Rapid Visual Screening Tools
- Closing Remarks

Risk Management: Types of Risk

- There are Several Types of Risk
  - Risk Assessment
  - Risk treatment
  - Risk acceptance
  - Risk Communication

Risk Assessment

- How much risk is there?
- The most popular type of risk
- Perhaps the easiest

- Not sufficient to just quantify risk!
  - More is needed

Risk Treatment

- Risk treatment deals with ways to
  - Mitigate risky conditions (shoring)
  - Avoid risks(hazard estimation, Structural retrofit)
  - Optimize risk(what is the best course of action that maximize safety at reasonable time and costs)
  - Transfer risk (other courses of action?)
  - Retain risk(moving ahead)

Risk Acceptance

- A decision to accept a risky situation
- The decision maker needs information to reach that decision
  - Potential of structural failure
  - Consequences of such failure
  - Consequences of inaction
  - Etc.
- Rapid Risk assessment tools can help in risk acceptance phase
  - Such tools are not currently available for near collapse buildings situations

Risk Communications

- Perhaps the most important, and least Utilized
- Sharing information about risk stake holders.
  - Is there a risk? (failure of building, or building component)
  - How much risk? (quantify risk in useful and practical terms)
  - Is it reasonable? (what is an acceptable risk?)
  - Can it be mitigated, or reduced?
  - What are the implications of retaining or transferring this risk?
- Need to describe risk in a fairly simple, accurate and efficient form

Components of Risk Assessment – 1

- Risk of a particular event can be defined in general terms as
  - Probability of an event X consequences of such an event
  - (Note the interrelationship between **risk** and **reliability**!)
- Fairly difficult to compute
- There are two simplified versions of the above definition

Components of Risk Assessment – 2

- A popular form of Risk assessment is
  - R = H . V . C
  - R = Risk measure
  - H = Hazard
    - Measures and identifies hazard probability, magnitude, etc.
  - V = Vulnerability
    - Estimates damages, capacities, behavior, retrofit
  - C = Consequences
    - Estimates costs-benefits, value, LCC, utilities
- Such a form is not suitable for near collapse buildings

Components of Risk Assessment – 3

- A more appropriate form of risk evaluation for near collapse buildings is
  - R = p(f) . C
  - P(f) = probability of failure
  - C= Consequences of such a failure
- Note that p(f) is the classical definition of structural **reliability**

Risk and Decision-Making – 1

- How much risk is acceptable? (risk acceptance)
- Would 30% risk be acceptable? How about 10% risk, or 90%?
  - The subject of thresholds
- Would same value of an acceptable risk (thresholds) be adequate for different situations?
  - Fire of a warehouse, or
  - Collapse of an apartment building?

Risk and Decision Making – 2

- Is risk (R) sufficient for accurate decision?
  - Do we also need reliability (might also be called Vulnerability to failure), p(f)?
- How risk should be communicated?
  - Graphical displays
  - Percentages / numbers
  - Audible sounds
  - Other?

Rapid Visual Screening Tools

- Tools should include **risk assessment**
  - Propensity (probability of failure)
  - Consequences of such failure
- Tools should include **decision making** aides
  - Acceptance limits (thresholds)
    - For risk
    - For probability of failure (reliability)
- All must be communicated in **accurate, simple, fast, and useful** fashion

Two Tools

- A tool that is specifically designed for field use by professionals in the field
  - Fast
  - Simple checklists
  - Limited, or no engineering background is needed
- A tool designed for use by engineers / architects, etc
  - More involved technically
  - Requires some engineering background
- The two tools should be based on the same technical principals (Risk / Decision making)

Evaluating Failure, p(f) – 1

- How do we evaluate possibility of failure rapidly?
  - Experience (existing documents and expertise)
  - Hazard specific
    - Seismic failure modes are different from blast failure modes
    - The tool will be aimed at IED attacks, it can be generalized later

Evaluating Failure, p(f) – 2

- The tools should address all potential failure modes
  - General stability
  - Local stability
  - Component stability
  - Non-structural components
- All of the above modes can be either brittle or ductile!

Evaluating Failure, p(f) – 3

- The tools should incorporate additional information, if available
  - Any sensor measurements
  - Any building plans
    - Use of BIM, when available
- Age / construction type and material
  - Steel braced frames are not the same as steel moment frames

Evaluating Consequences of Failure

- If this particular item fails, what will happen?
  - Localized failures?
  - Global failure?
  - Other?

Communicating Results

- The tools should include several means to communicate the results
  - Graphical: charts, pictures, etc.
  - Numbers

Closing Remarks

- Implementing risk and decision making techniques into Building stabilization community is a challenging task
- Requires collaboration of major stakeholders
- The tools are needed, the technology is there
- So, let us do it!!

Mohammed Ettouney

A bio of Dr. Ettouney can be found on page 7.

Earle Kennett

As Chief Operating Officer of the National Institute of Building Sciences, Earle Kennett is responsible for and oversees all Institute technical programs and is the organization's second in command.

Prior to becoming the Institute Chief Operating Officer, he managed and directed hundreds of projects for Federal agencies in building science, architecture, and engineering as Vice President at the National Institute of Building Sciences (NIBS) and past Administrator for Research for the American Institute of Architects (AIA).

He presently manages a number of technical programs, including contracts with the Department of Veterans Affairs, NASA, Department of Energy, the Department of Defense, the Naval Facilities Engineering Command, the Army Corps of Engineers, the Air Force, the Department of Homeland Security, Department of Education, Federal Emergency Management Agency, and the General Services Administration. The buildingSMART Alliance, the National CAD Standard, the National BIM Standard, ProjNet(sm), the Building Enclosure Technology and Environmental Council (BETEC), the High Performance Building Council (HPBC), the Facility Maintenance and Operations Committee (FMOC), Construction Operations Building Information Exchange (COBIE), Specifier's Product Information Exchange (SPiE), and the National Clearinghouse for Educational Facilities (NCEF) are under his direction.

He also manages a program concerned with incorporating a large number of design and construction criteria on a Web site. This system, the Whole Building Design Guide (WBDG) is an innovative concept in information use in the construction industry. It is probably the largest Web site in the building community. The system presently has over 250,000 users and over 2 million documents downloads on a monthly basis, involves over 15 Federal agencies, and has become the sole portal for the distribution of uniform facility criteria for the military services.

Before coming to NIBS Mr. Kennett was Administrator for Research at the American Institute of Architects, where he also managed various large and complex building research projects including managing the development of the energy professional development program for the American Institute of Architects, which was the largest individual continuing education program the AIA had embarked upon.

He has taught a range of technical architectural courses at the University of Maryland, Florida A&M University, and the Washington-Alexandria Center for Virginia Polytechnic Institute and State University.

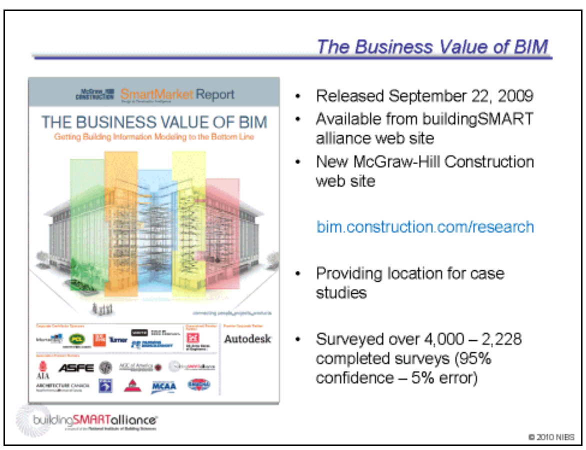
In 1976 he received his bachelor of architecture with highest honors from the School of Architecture at the University of Tennessee, where he received the Chancellor's Citation for Extraordinary Academic Achievement. He also has a bachelor of engineering from Memphis State University.

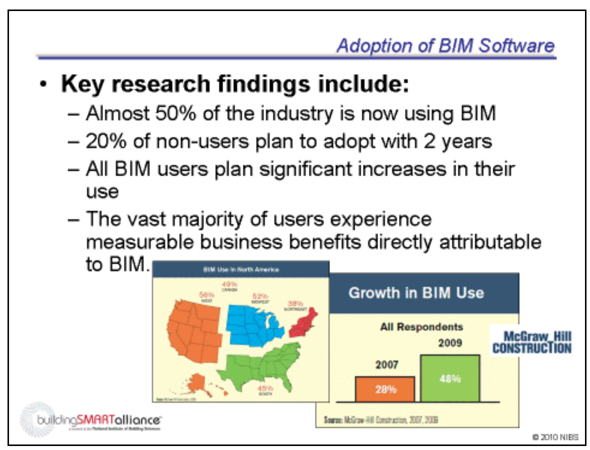
SESSION 4
EMERGING TECHNOLOGIES

BIM Basics and Utilization for Building Stabilization Efforts

Building Information Modeling (BIM) is emerging to be an important tool for all building stakeholders. It can be an invaluable tool for emergency managers after an IED attack that causes buildings to be in a near-collapse condition. This presentation offers some basics of BIM. The presentation then explores the ways that BIM can be of help to emergency managers.

Presentation Slides





Desired Outcome of BIM

1. Collect data once and use from inception onward and allow information to flow
   - Authoritative source collects information and records metadata
   - Information assurance is in place to protect intellectual property
   - Multi faceted analysis is supported by software
   - Facility management uses information for operations and sustainment
   - All facets of the lifecycle are supported

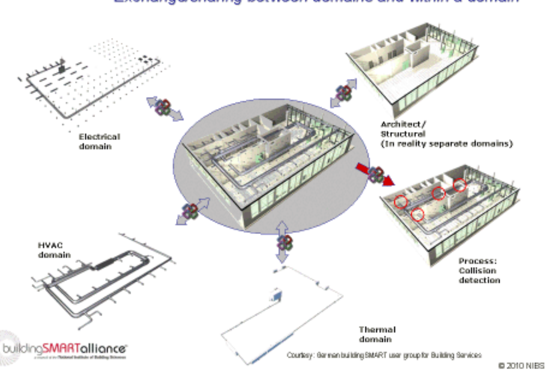
Desired Outcome of BIM

2. Build facilities electronically and completely before we build them physically. "Build a model then build the model"
   - Reduces risk and therefore litigation
   - Reduces RFI's and change orders
   - Allows more activities to occur in parallel thus speeding delivery
   - Provides better estimates
   - Delivers true as-built

Courtesy Dennis Shelden – Gehry Technologies

Multiple BIM authoring tools

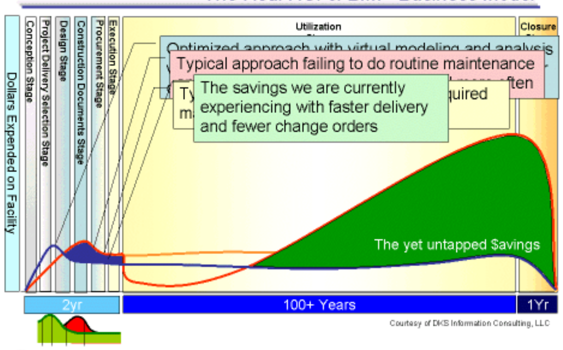
Exchange/sharing between domains and within a domain



Courtesy: German building SMART user group for Building Services

Truly The Big Picture

The Real ROI of BIM - Business Model



Courtesy of DKS Information Consulting, LLC

buildingSMART alliance

- News
- Events
- Information about the Alliance
- **Programs**
- **Projects**
- **Interest Groups**
- Speakers Bureau
- Affiliated Associations
- Discussion Forums

States Requiring BIM
State of Wisconsin - Department of
ADMINISTRATION
Division of State Facilities
Division of State Facilities
Master Specifications/Design Guidelines
DSF BIM Guidelines & Standards
TFC
Texas Facilities Commission
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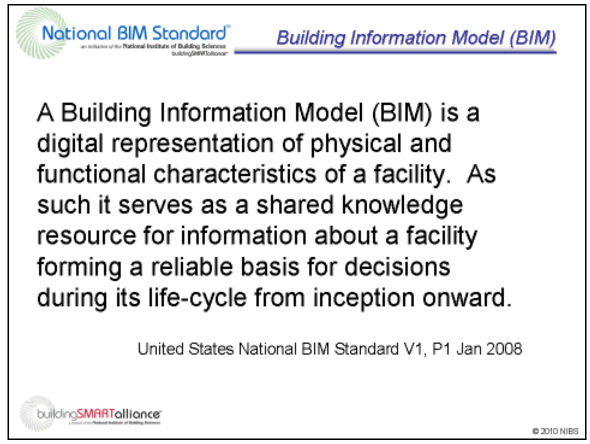

National BIM Standard
Building Information Model (BIM)
A Building Information Model (BIM) is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward.
United States National BIM Standard V1, P1 Jan 2008
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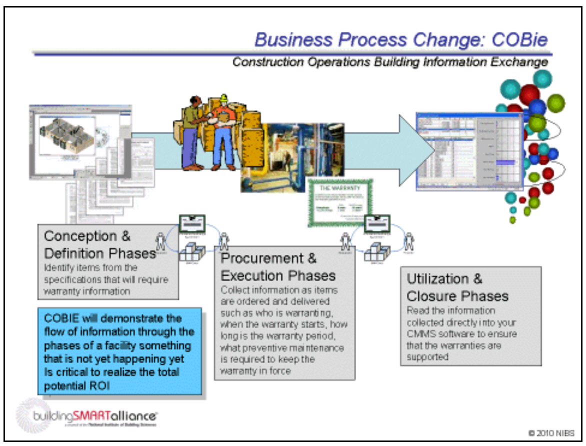

Business Process Change: COBie
Construction Operations Building Information Exchange
Conception & Definition Phases
Identify items from the specifications that will require warranty information
Procurement & Execution Phases
Collect information as items are ordered and delivered such as who is warranting, when the warranty starts, how long is the warranty period, what preventive maintenance is required to keep the warranty in force
Utilization & Closure Phases
Read the information collected directly into your CMMS software to ensure that the warranties are supported
COBIE will demonstrate the flow of information through the phases of a facility something that is not yet happening yet Is critical to realize the total potential ROI
THE WARRANTY
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Maintaining Information Must Be Part of Doing Business
Product Selection
Analysis
Ordering & Invoicing
Maintain
COBIE
Close Work Order When Model is Updated
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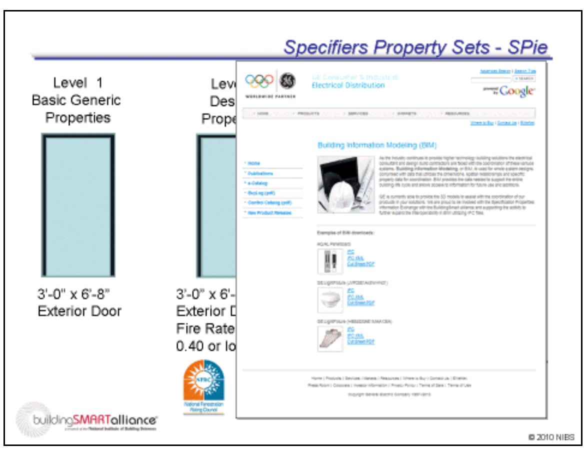

Specifiers Property Sets - SPie
Level 1
Basic Generic Properties
3'-0" x 6'-8"
Exterior Door
Leve
Des
Prope
3'-0" x 6'-
Exterior D
Fire Rate
0.40 or lo
Electrical Distribution
Building Information Modeling (BIM)
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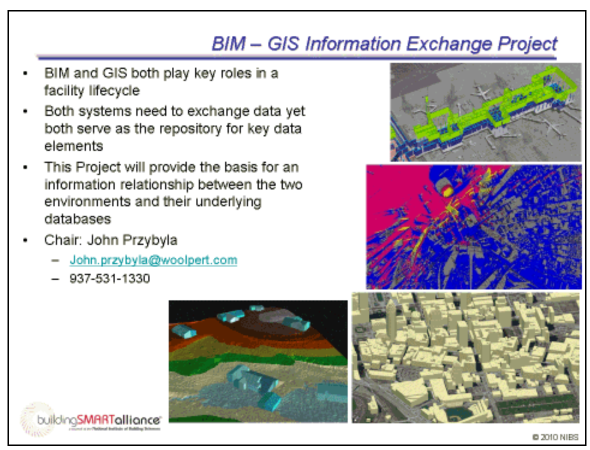

BIM – GIS Information Exchange Project
• BIM and GIS both play key roles in a facility lifecycle
• Both systems need to exchange data yet both serve as the repository for key data elements
• This Project will provide the basis for an information relationship between the two environments and their underlying databases
• Chair: John Przybyla
– John.przybyla@woolpert.com
– 937-531-1330
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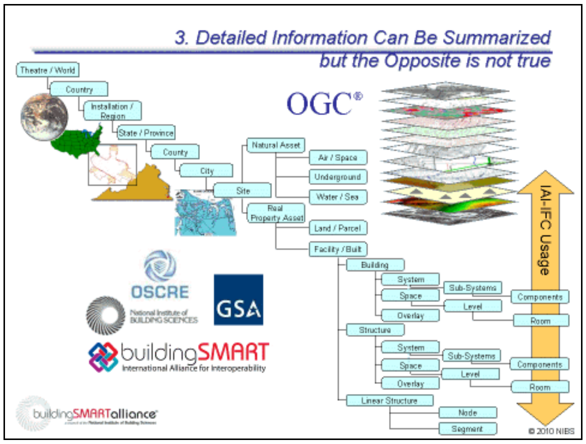

3. Detailed Information Can Be Summarized
but the Opposite is not true
Theatre / World
Country
Installation / Region
State / Province
County
City
Site
Natural Asset
Real Property Asset
Air / Space
Underground
Water / Sea
Land / Parcel
Facility / Bulit
Building
System
Sub-Systems
Space
Level
Overlay
Components
Room
Structure
Linear Structure
Node
Segment
OGC®
IAI-IFC Usage
OSCRE
National Institute of BUILDING SCIENCES
GSA
buildingSMART
International Alliance for Interoperability
buildingSMARTalliance
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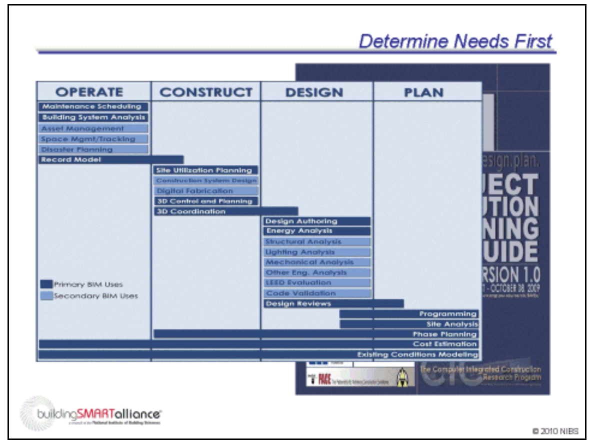

Determine Needs First
OPERATE
CONSTRUCT
DESIGN
PLAN
Maintenance Scheduling
Building System Analysis
Asset Management
Space Mgmt/Tracking
Disaster Planning
Record Model
Site Utilization Planning
Construction System Design
Digital Fabrication
3D Control and Planning
3D Coordination
Design Authoring
Energy Analysis
Structural Analysis
Lighting Analysis
Mechanical Analysis
Other Eng. Analysis
LEED Evaluation
Code Validation
Design Reviews
Programming
Site Analysis
Phase Planning
Cost Estimation
Existing Conditions Modeling
Primary BIM Uses
Secondary BIM Uses
The Computer Integrated Construction Research Program
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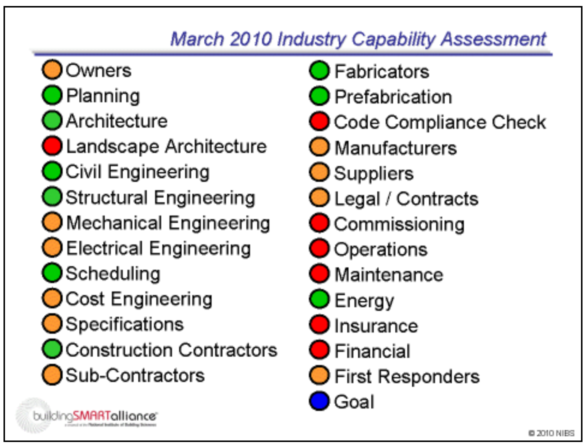

March 2010 Industry Capability Assessment
Owners
Planning
Architecture
Landscape Architecture
Civil Engineering
Structural Engineering
Mechanical Engineering
Electrical Engineering
Scheduling
Cost Engineering
Specifications
Construction Contractors
Sub-Contractors
Fabricators
Prefabrication
Code Compliance Check
Manufacturers
Suppliers
Legal / Contracts
Commissioning
Operations
Maintenance
Energy
Insurance
Financial
First Responders
Goal
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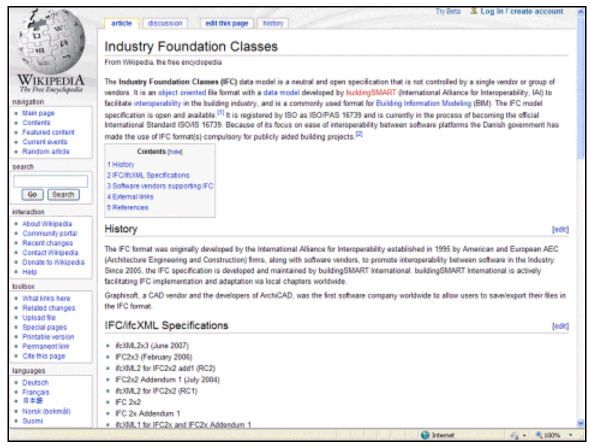

Wikipedia
The Free Encyclopedia
article
discussion
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history
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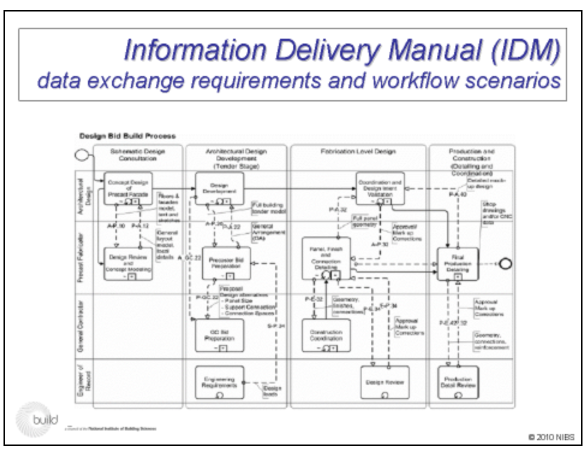
Industry Foundation Classes
From Wikipedia, the free encyclopedia
Contents
1 History
2 IFC/ifcXML Specifications
3 Software vendors supporting IFC
4 External links
5 References
History
IFC/ifcXML Specifications



Information Delivery Manual (IDM)
data exchange requirements and workflow scenarios
Design Bid Build Process
Schematic Design Consultation
Architectural Design Development (Tender Stage)
Fabrication Level Design
Production and Construction (Detailing and Coordination)
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Ahmed Al-Ostaz

Dr. Ahmed Al-Ostaz is an Associate Professor of Civil Engineering at the University of Mississippi (Ole Miss). Before joining Ole Miss in 2002, Dr. Al-Ostaz was a Visiting Assistant Professor at Composite Materials and Structures Center and an Adjunct Assistant Professor in the Department of Materials Science and Mechanics at Michigan State University. He focuses his research on utilizing advanced materials (nano-enhanced, bio inspired, and self-healing materials) in structural applications using multi-scale experimental and numerical tools. He published more than 50 journal and conference papers.

Dr. Al-Ostaz has been the PI and Co-PI on research projects funded by Office of Naval Research, Department of Home Land Security, Air Force Lab (AFL), NASA EPSCoR, Mississippi Space Consortium, Michigan Department of Transportation, Mississippi Department of Transportation, General Motors Company, Research of Excellence Funds (State of Michigan) and NSF-SBIR program with a total funding of more than $5 million. Currently he is a Co-PI in two major research projects sponsored by the Department of Homeland Security Science and Technology Directorate (DHS S&T) through the Southeast Region Research Initiative (SERRI) administered by Oak Ridge National Laboratory, and one project funded by Office of Naval Research. He was selected by faculty, students, and the engineering alumni of the school of engineering at the University of Mississippi as the Outstanding Engineering Faculty Member of the Year during the academic year 2005-2006.

Current Technologies in Materials and Rapidly Deployable Shoring, Stabilizing and Piping Equipments for Building Stabilization after IED Attacks

This paper examines the advantages and disadvantages of current technologies in materials and rapidly deployable shoring, stabilizing and piping equipments for building stabilization after IED attacks, with special emphasis on using composite materials. One of the main disadvantages of using wood shoring is its unpredictable, sudden, and brittle failure. Recently, composite materials have been used as flexural reinforcement in wood beams for transportation infrastructure applications. This paper reports the results of a preliminary study investigating the use of glass fiber-reinforced plastic (FRP) to reinforce short wood beams for improving both shear and flexural strengths. E-glass fibers in pre-impregnated, woven and stitched forms were investigated with resorcinol (phenol formaldehyde), epoxy and vinyl ester as resins/adhesives. The experimental program consisted of small-specimen tests to determine material properties, and large-specimen beam tests. The study demonstrates that polymer composite shear reinforcement is effective in increasing the overall strength of shear critical beams and providing ductility. Preliminary tests at University of Mississippi showed that ductility of wood columns improves significantly by retrofitting wood with FRP. Expansion and contraction of the wood with FRP wrapping has also been tested. A test plan for testing wood columns with a UV cure resin is presented. Nano-additives are also considered in the test program.

Presentation Slides

CURRENT TECHNOLOGIES IN MATERIALS AND RAPIDLY DEPLOYABLE SHORING, STABILIZING AND PIPING EQUIPMENTS FOR BUILDING STABILIZATION AFTER IED ATTACKS

Ahmed Al-Ostaz [(1)], Chris Mullen[(1)] ,Alexander Cheng [(1)], and Edward Fyfe[(2)]

[(1)]University of Mississippi
[(2)] Fyfe Co. LLC

Near-Collapse Buildings Workshop for Emergency Management Personnel
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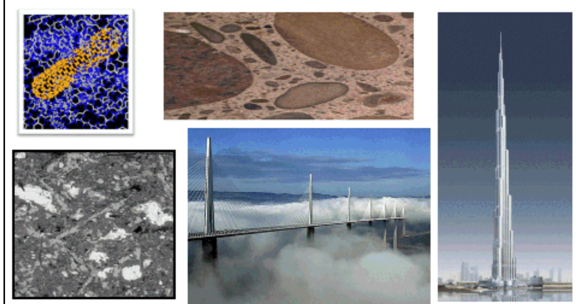
From Nanostructure to Infrastructure



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OUTLINE

- Motivation /Problem Statement
- Proposed Approach (4-D)
- Gaps and Need for Research

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PROBLEM STATEMENT

- A benchmark analysis /design of infrastructure facilities subject to blast and other extreme loadings, which includes disaster simulation, mapping protection barrier, evacuation procedure, and proposing structure improvement through retrofitting and the use of high-performance materials, including nano-structured materials.

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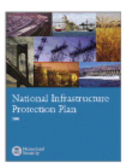
Relevance to DHS S&T Objectives

Build a safer, more secure, and more resilient America by enhancing protection of the Nation's critical infrastructure and key resources to prevent, deter, neutralize, or mitigate the effects of deliberate efforts by terrorists to destroy, incapacitate, or exploit them; and to strengthen national preparedness, timely response, and rapid recovery in the event of an attack, natural disaster, or other emergency. (The National Infrastructure Protection Plan, DHS, 2006)



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Motivation

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Motivation

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Protection Against IED Attack

4-D Approach

- Deny
- Detect
- Delay
- Defend

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Deny………

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Protection Philosophy

- Bloom's First Law of Explosive:
  - " If some is good, more is better"
- Wilson's Threat Corllary:
  - " No matter how bad the threat, there is always something worse"
- Most structures do not have weapon effects resistance as part of their primary performance parameters
- Addition of passive protection must be done in a manner that does the least to compromise the function of the structure
- Key to reasonable application or installation is a careful analysis of likely threat environment
- **Generally better to prevent attack or mitigate severity than to Strengthen structure to high levels.**

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Primary Threat Weapon Effects

- Three major categories of threat weapon explosions:
  1. External air blast (External AIREX)
  2. Internal air blast (internal AIREX)
  3. Underwater explosion (UNDEX)
- Each category produces distinct aspects of pressure loading and other weapon effects on the target structure
- Attack may combine two or three categories (example: USS COLE)
  - Underwater explosions can generate air blast
  - Air explosions can transmit underwater pressure
  - An explosion in either air or water can propagate pressure into an enclosed volume through venting
- All categories may be preceded or followed by penetration/ perforation of the target structure

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Detect………

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Global vs local measurements

- The physical lengths associated with buildings make many of the localized methods ineffective for detecting damage over a significant part of the structure.
- A systematic effort is required to assess the effectiveness of sensing methods that have been developed for other applications, and select and enhance a set of techniques that will be effective for the application in hand.

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Steps to be followed

- First visual inspection need to be employed.
- Then a rapid and simple technique, such as digital speckle interferometry or vibration testing, will be first used to scan a structural component for anomalies that suggest flaws such as disbonds or cracks.
- Based on findings, a decision is made to use another technique, such as thermal imaging or dielectric measurement, to obtain more data about the anomaly.
- Fore detecting pre-**brittle** failure, localized material measurements need to be employed (Electrochemical spectroscopy, Resonance ultrasound spectroscopy,….etc).

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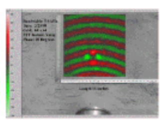
Brittle Failure …. ?



A. Al-Ostaz , W. Wu, H. Alkhate, K.I. Alzebdeh b, *Computational Materials Science* **46** (2009) 1144–1151

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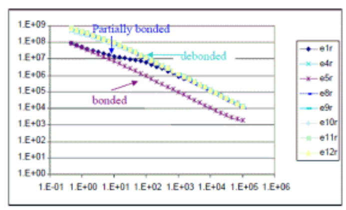
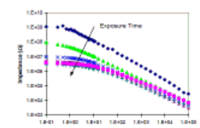
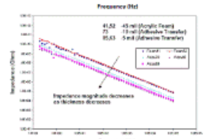
EIS







Al-Ostaz, A, P. R. Mantena, M. Anakapali and S. J. Wang, *J. Adhesion Sci. Technol.* ***2007***, *21: 3-4*:339

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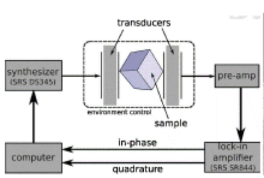
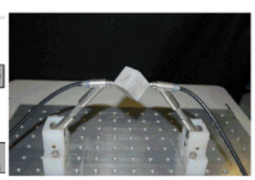
RUS





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Delay………

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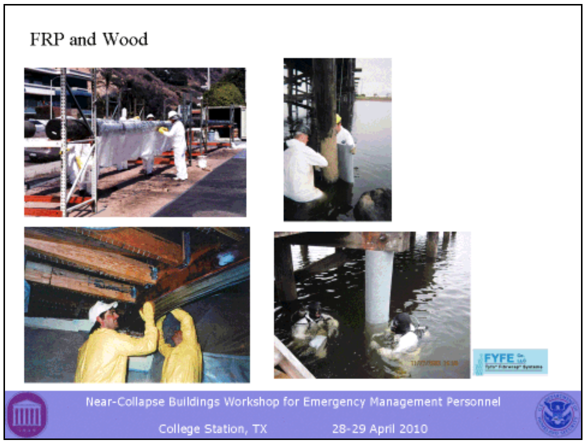
FRP and Wood
FYFE
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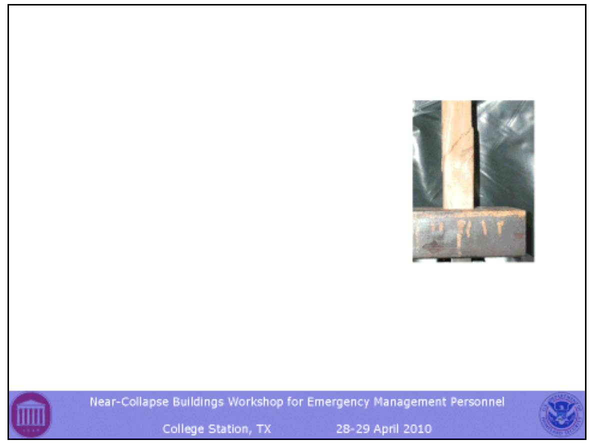
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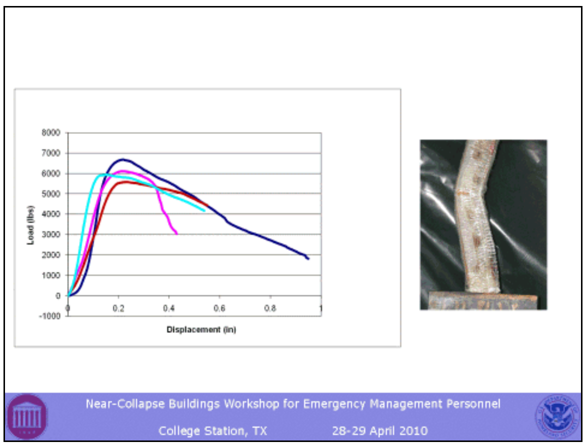
Load (lbs)
Displacement (in)
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
0
0.2
0.4
0.6
0.8
1
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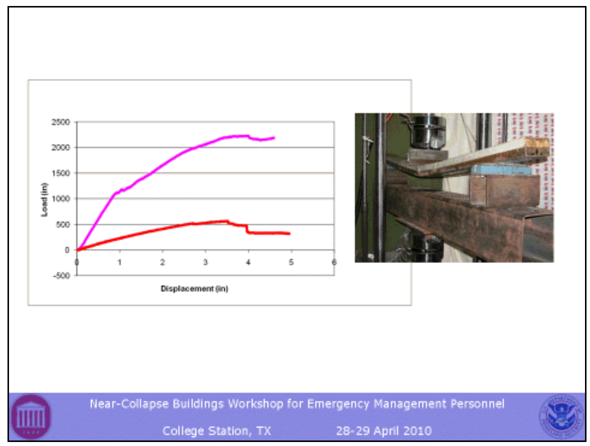
Load (in)
Displacement (in)
2500
2000
1500
1000
500
0
-500
0
1
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3
4
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6
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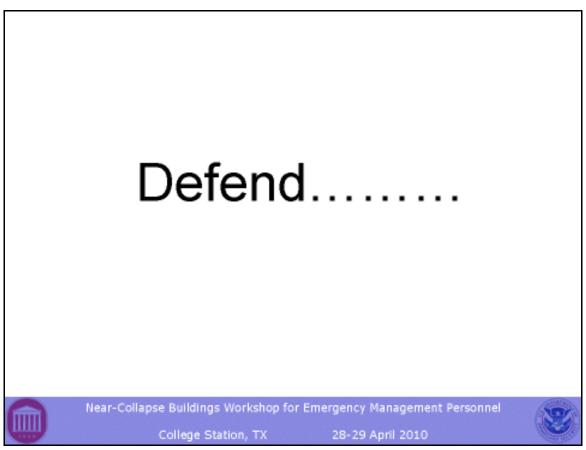
Defend.........
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ERDC Experiments
hop for Em
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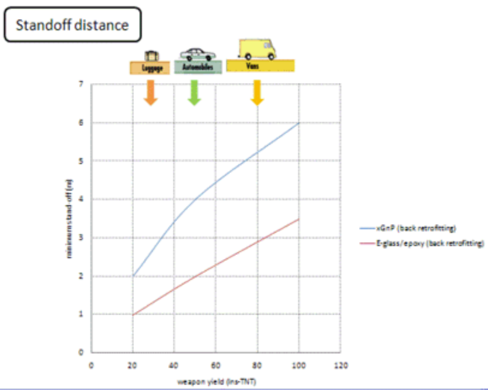

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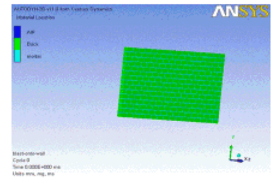
Nano Material-CMU Non retrofitted

- Experimental
- Simulation



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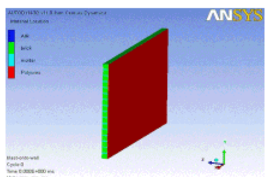
Nano Material- CMU Polyurea

- Experimental
- Simulation



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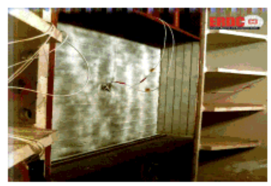
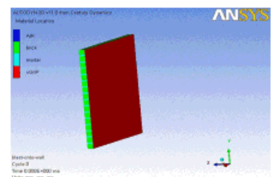
Nano Material-CMU xGnP

- Experimental
- Simulation





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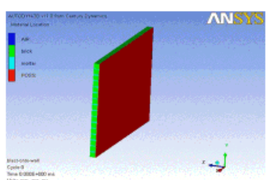
Nano Material- CMU POSS

- Experimental
- Simulation



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Gaps and Needs of Research

1. Establishing a Simplified Air-Blast Tools for Quick Calculations of Range of Explosives: Retrofitting / performance Based Design
2. Developing data base of failure scenarios using recent advances in computer modeling technologies.
3. Use of Advanced Materials and Repair Technologies
4. Add A second Layer of Vulnerability: Fire, Hurricanes, Earthquake

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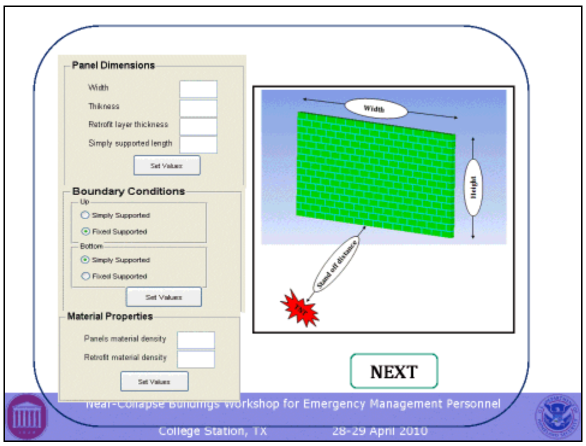
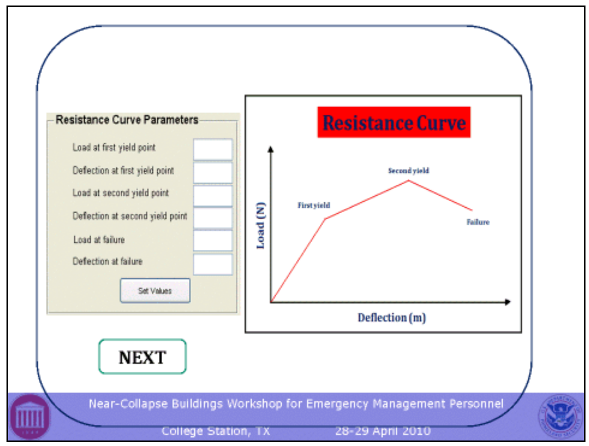
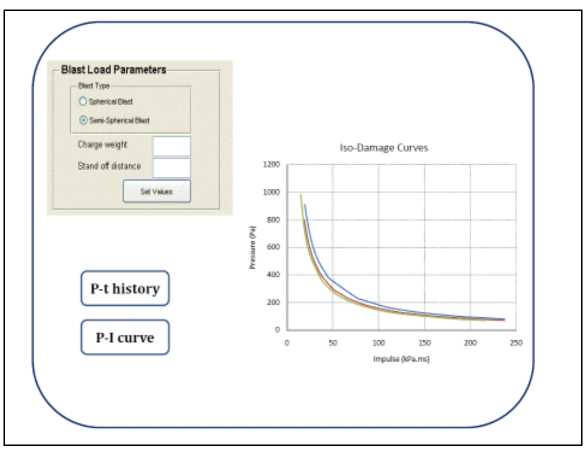
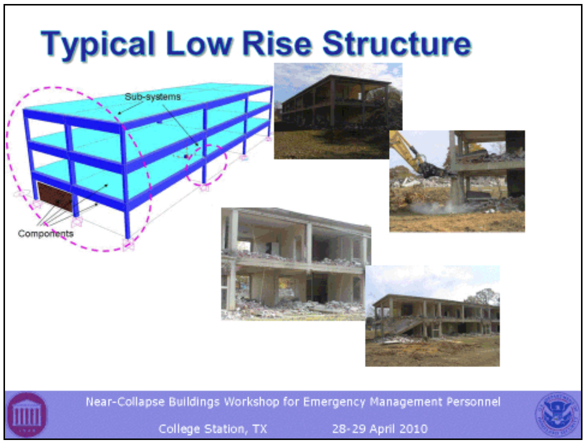
Establishing a Simplified Air-Blast Tools for Quick Calculations of Range of Explosives: Retrofitting / performance Based Design







Developing data base of failure scenarios using recent advances in computer modeling technologies


Typical Low Rise Structure
Sub-systems
Components
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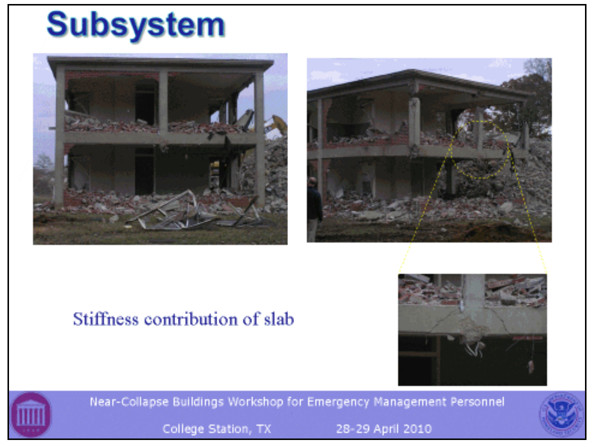
Subsystem
Stiffness contribution of slab
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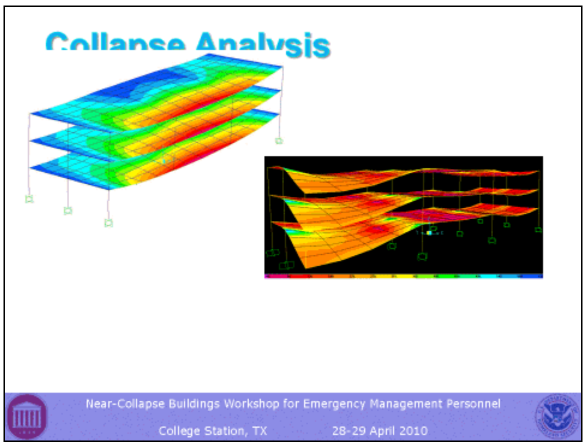
Collapse Analysis
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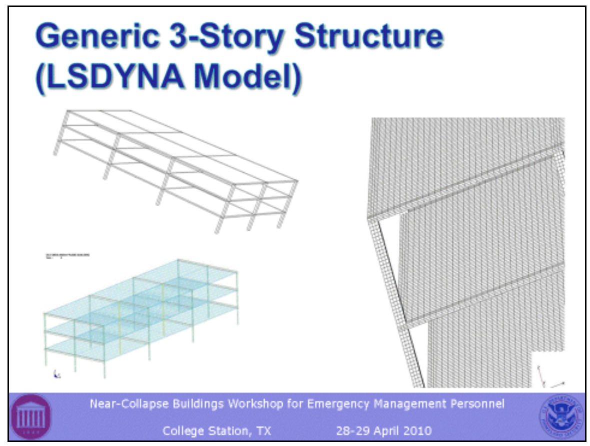
Generic 3-Story Structure
(LSDYNA Model)
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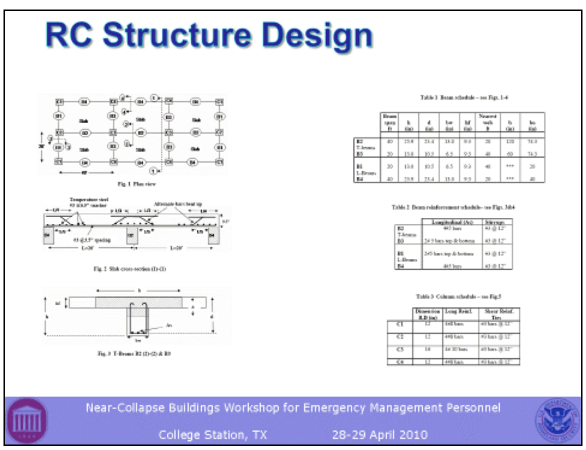
RC Structure Design
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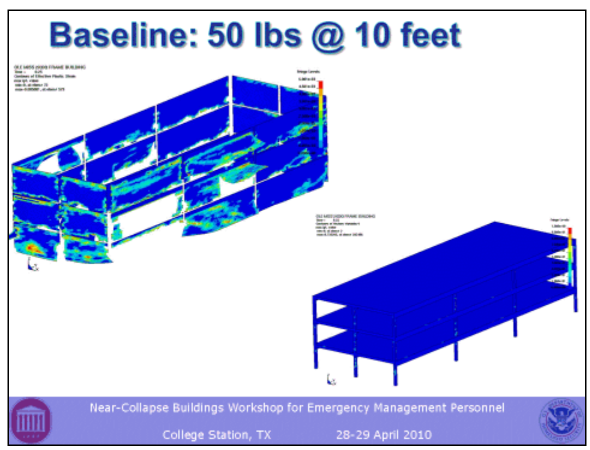
Baseline: 50 lbs @ 10 feet
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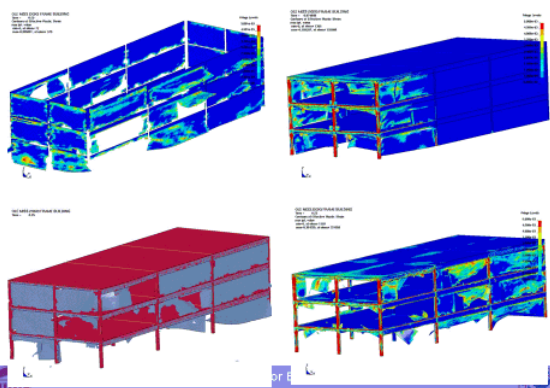
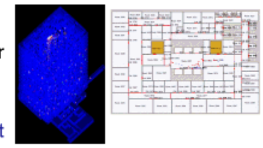
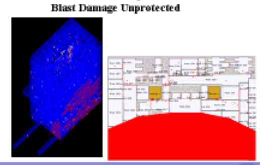


Evacuation Scenario Simulations

- Scenario 1:
  Undamaged Building Under Normal Operation
- Scenario 2:
  Building Damaged by Blast without Nano-Particle Composites
- Scenario 3:
  Building Damaged by Blast with Nano-Particle Composites



Above: Normal Operation Below: Blast Damage Unprotected



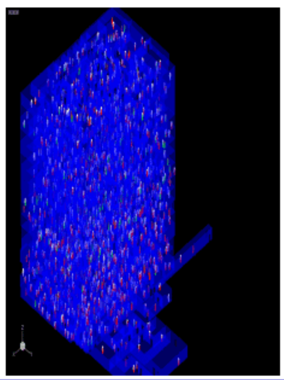
Multi-Scenario Simulations

Scenario 3: Nano-Reinforced Structure Subject to Damage

Simulation Statistics

Simulation Time	00:15:14
Running Time	00:16:44
Total Agents	1961
Total Escaped	1418
Total Died	289
Basement	0
Floor 1	30
Floor 2	20
Floor 3	136
Floor 4	19
Floor 5	7
Floor 6	10
Floor 7	1
Floor 8	146
Floor 9	2
Floor 10	3
Floor 11	1

Close



Use of Advanced Materials and Repair Technologies

- Lightweight, rapidly deployable materials/systems for shoring, pinning, bracing, and other temporary structural support purposes.
  - FRP for strengthening damaged columns and beams
  - FRP for retrofitting wood pinning and shoring members
  - Composite fixtures for strengthening column-beam connections
  - Polymer sprays for strengthening walls and floors
  - Polymer concrete for rapid concrete repair
- Material database for quick selection of repair materials and techniques.
- New emerging Technologies:
  - **Multi-functional** low-cost nano particle additives, such as nano clay, POSS, XGnP, Tripoli, cellulose whiskers, etc. to enhance the structural performance of polymer composites.

Mechanics Based Design

- Performance needed: Blast, impact, penetration, earthquake, fire, aging, corrosion, energy absorbing…
- Material properties: Tensile strength, hardness, ductility, brittleness, damping, viscoelastic, memory, rate dependent …
- Which material property delivers what performance?
- Answer these questions based on physical-mechanical laws

What is Engineering Design?

- Structural design: Given a material, we seek the most effective and efficient design to deliver the maximum performance. (We put the material where it is needed)
- Material design: When we reached the limit of structural design, we seek materials with better performance (at a cost)
- Design material: When existing materials cannot deliver the performance, we seek to design (new) materials

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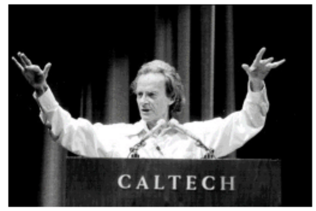
"*There's plenty of room at the bottom*" (Richard Feynman)



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Nano Materials

- During the last two decades, tremendous progress has been made in nanoscience
- New classes of nano materials, such as carbon nanotubes, nanowire, quantum dot, are being assembled, atom by atom, with different applications in mind—electronics, biomedicine, energy, environment
- However, these materials are still rare and quite expensive

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- For the protection of the nation's critical infrastructure, we need nano materials, that are *low cost* and in *huge quantity*
- Not all nano materials are man-made and expensive. There are many naturally occurring materials that are at or near nano size, such as nanoclay, volcanic and fly ash, and other minerals
- These materials are low cost and abundant in quantity for infrastructure protection

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Ultimate Scientific Goal

- Design material physical principles: If we know how nano particles alter and improve upon material properties based on physical and mechanical laws, then we may be able to "design" infrastructure materials for the desirable performance, such as tensile strength, ductility, brittleness, energy dissipation, etc., required for different protection types (blast, impact, fire resistance, …).

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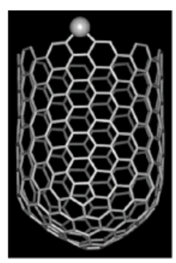
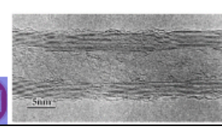
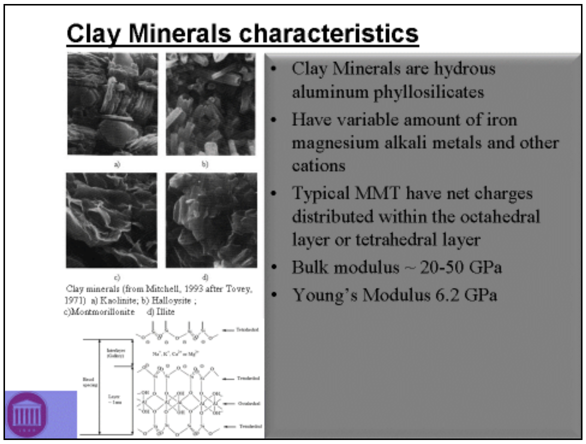
Carbon nanotube characteristics

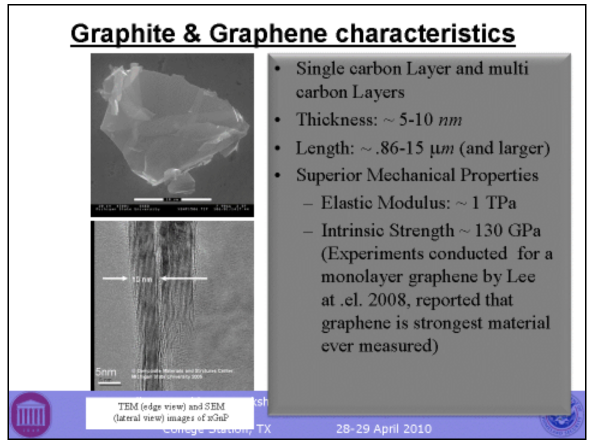




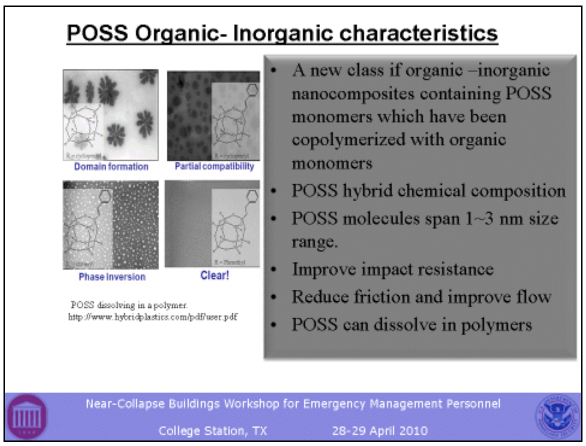
- Single-wall carbon nanotubes and multi-wall carbon nanotubes
- Diameter: ~ 1 *nm*
- Length: ~ 100 µ*m* (and larger)
- Superior Mechanical Properties
  - Elastic Modulus: ~ 1 TPa
  - Density 1/6th of steel
  - Conductive ability is 100,000 times that of copper
  - Yield Strain: More than 4%
  - Buckling Strain: ~ 5% (aspect ratio of 1/6)



Clay Minerals characteristics
Clay Minerals are hydrous aluminum phyllosilicates
Have variable amount of iron magnesium alkali metals and other cations
Typical MMT have net charges distributed within the octahedral layer or tetrahedral layer
Bulk modulus ~ 20-50 GPa
Young's Modulus 6.2 GPa
Clay minerals (from Mitchell, 1993 after Tovey, 1971) a) Kaolinite; b) Halloysite ; c)Montmorillonite d) Illite



Graphite & Graphene characteristics
Single carbon Layer and multi carbon Layers
Thickness: ~ 5-10 nm
Length: ~ .86-15 μm (and larger)
Superior Mechanical Properties
Elastic Modulus: ~ 1 TPa
Intrinsic Strength ~ 130 GPa (Experiments conducted for a monolayer graphene by Lee at .el. 2008, reported that graphene is strongest material ever measured)
TEM (edge view) and SEM (lateral view) images of xGnP
28-29 April 2010



POSS Organic- Inorganic characteristics
A new class if organic –inorganic nanocomposites containing POSS monomers which have been copolymerized with organic monomers
POSS hybrid chemical composition
POSS molecules span 1~3 nm size range.
Improve impact resistance
Reduce friction and improve flow
POSS can dissolve in polymers
Domain formation
Partial compatibility
Phase inversion
Clear!
POSS dissolving in a polymer
http://www.hybridplastics.com/pdf/user.pdf
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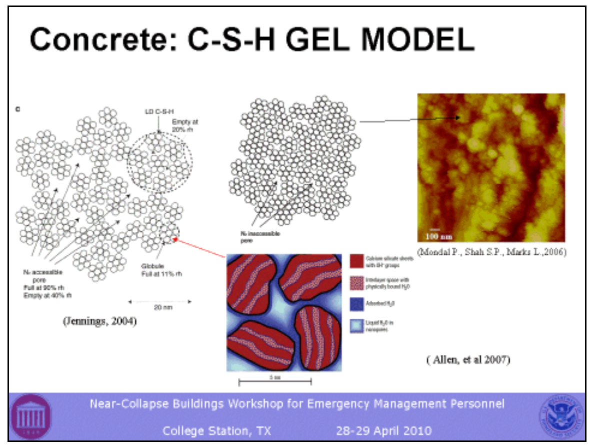

Concrete: C-S-H GEL MODEL
(Jennings, 2004)
(Mondal P., Shah S.P., Marks L.,2006)
(Allen, et al 2007)
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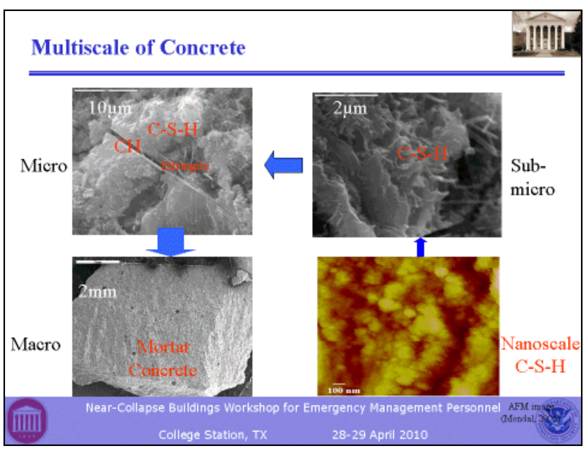

Multiscale of Concrete
Micro
10μm
C-S-H
CH
2μm
C-S-H
Sub-micro
Macro
2mm
Mortar
Concrete
Nanoscale C-S-H
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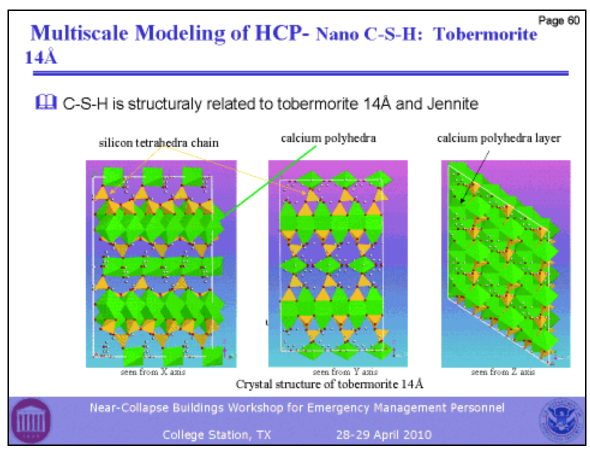
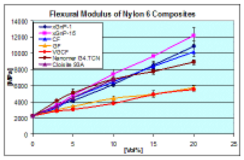
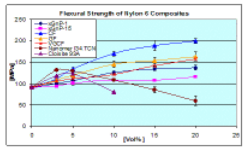


Page 60
Multiscale Modeling of HCP- Nano C-S-H: Tobermorite 14Å
C-S-H is structuraly related to tobermorite 14Å and Jennite
silicon tetrahedra chain
calcium polyhedra
calcium polyhedra layer
seen from X axis
seen from Y axis
seen from Z axis
Crystal structure of tobermorite 14Å
Near-Collapse Buildings Workshop for Emergency Management Personnel
College Station, TX 28-29 April 2010

Is nao always good..?



Whereas adding nano particles may increase strength, it will increase modulus and thus reduce ductility of materials.



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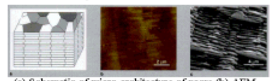
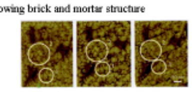
Natural Nanocomposites: See-shells (Nacre-Mother of Pearl)

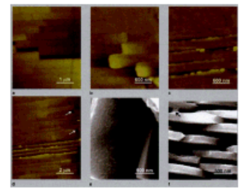
- *What is the secret recipe that mother nature uses to fabricate see-shells?*
- *What roles do the nanoscale structure play in the inelasticity and toughness of see shells?*
- *Can we produce see-shell like materials?*



(a) Schematic of micro-architecture of nacre (b) AFM of fractured surface © SEM of fractured surface showing brick and mortar structure



Rotation and deformation of nanoparticles in nacre platelet during three point bending



Atomic force microscopy images of (a) crack deflection, (b) crack extrusion, © particles squeezed out at the platelet interface (d) slip bands and separation at the platelet interface, indicated by arrows (e) SEM of nanoscale asperities on the aragonite surface (f) the organic polymer that serves as adhesive to hold the platelets together as indicated by the arrow.

X. Li, JOM; Mar 2007; 59(3):pg 71

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Mechanisms of toughness…!!!

- Crack deflection
- Deformation of aragonite platelets
- Aragonite platelets slip
- Aragonite adhesive interlayer
- Interlock from platelet surface nanocomposites
- Rotation and deformation of nanocomposites

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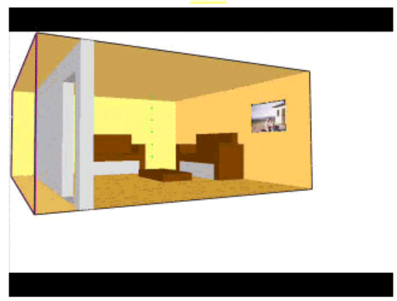
Fire Dynamic Simulator

- Soot



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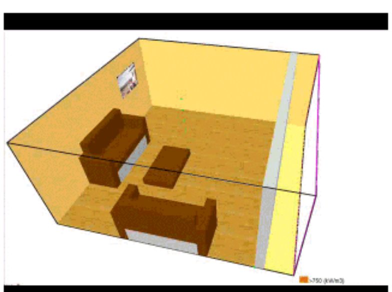
Fire Dynamic Simulator

- Flame



Near-Collapse Buildings Workshop for Emergency Management Personnel

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David Mascarenas

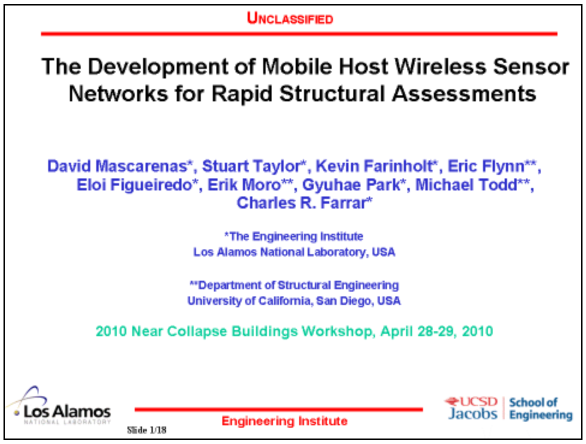
David Mascarenas recently joined the Engineering Institute at Los Alamos National Lab as a director-funded postdoctoral fellow. David received his Ph.D. in Structural Engineering from UCSD, advised by Professor Michael Todd. David has been an integral part of the institute's research in structural health monitoring and wireless hardware development. His Ph.D. dissertation involved the development of a novel "mobile host" wireless sensor network, where a small-scale helicopter platform was used as a mobile host to wirelessly deliver energy to sensor nodes on as-needed basis. Once a sensor node was energized, it would make a measurement and wirelessly transmit the data back to the helicopter for storage and further analysis. His work was highlighted in the April 2008 issue of Sound and Vibration Magazine. For his postdoctoral research, David is currently working on high-speed, autonomous unmanned ground vehicle escape and evasion. This work is vital to developing tamper-resistant unmanned ground vehicles that are robust when confronted by hostile agents.

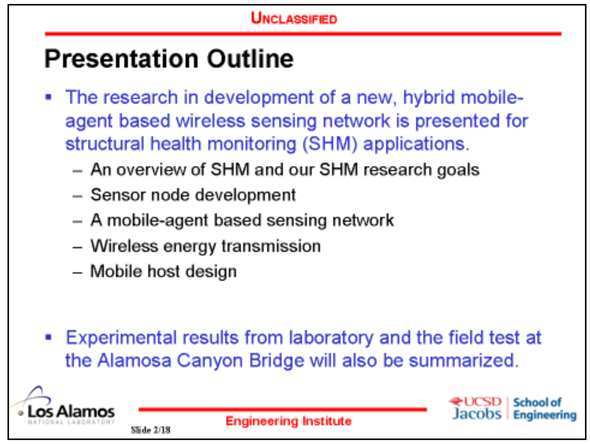
The Development of Mobile Host Wireless Sensor Networks for Rapid Structural Assessments

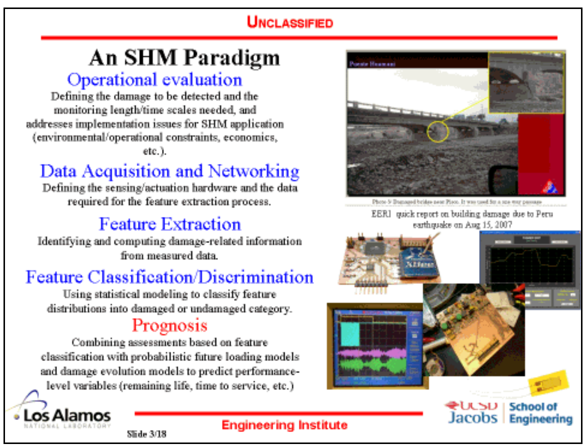
This presentation summarizes the work at the Los Alamos National Labs Engineering Institute to develop "mobile host" wireless sensor networks. These networks facilitate the rapid assessment of structural integrity in the event of natural or man-made disasters. Mobile host wireless sensor networks have the potential to rapidly asses the structural integrity of a building that has experienced an IED or other extreme event. By presenting this work we hope to receive feedback from the first responder community to help us guide the path of further research.

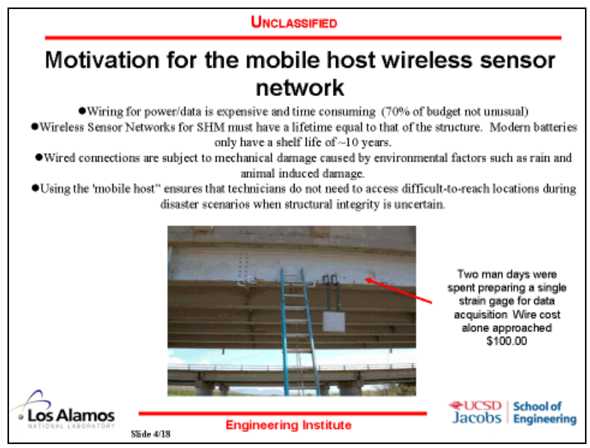
In the event of a natural or man-made disaster, the structural integrity of civil infrastructure may be in question. In these circumstances, decision makers require structural integrity assessments, and the current state of the art is rapid visual screening. Unfortunately, accessibility and safety concerns often delay the execution of the necessary site surveys, which in turn compounds the economic impact of such disasters. Structural Health Monitoring (SHM) wireless sensor networks can quickly provide the data collection necessary for rapid structural assessment without endangering human lives. Technical challenges affecting the deployment of such a network include ensuring power is maintained at the sensor nodes, reducing installation and maintenance costs, and automating the collection and analysis of data provided by a wireless sensor network. Los Alamos National Labs has been investigating the "mobile host" approach to these problems. This architecture utilizes novel sensor nodes that are deployed without resident power. A mobile host, such as UAV, UGV, or teleoperated-vehicle, is used on an as-needed basis to provide the required electric power to the nodes by wireless energy transmission and subsequently retrieve the data by wireless interrogation. The mobile host may be guided to any deployed node that requires interrogation. Furthermore, mobile hosts can be configured to access areas inaccessible to human personnel. To date, the mobile host wireless sensor network has been demonstrated in the field using both air- and ground-based mobile hosts. Ongoing work is concerned with developing path planning algorithms for quickly negotiating rough terrain with the mobile host, terrain classification, algorithms for executing tactical maneuvers (e.g., PIT maneuver), and distributed computing across the wireless sensor network. These tools will help enable rapid structural assessments after extreme events, while minimizing risk to personnel.

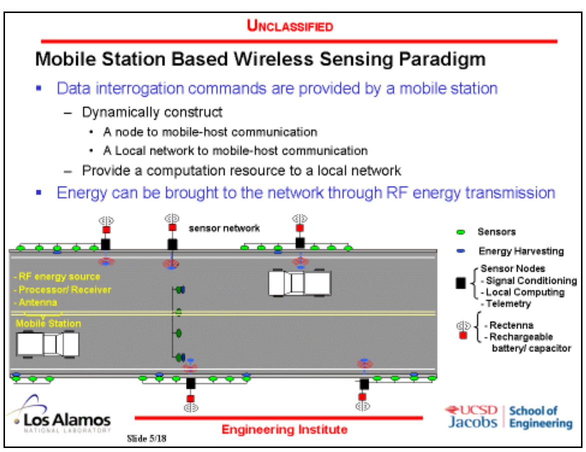
Presentation Slides

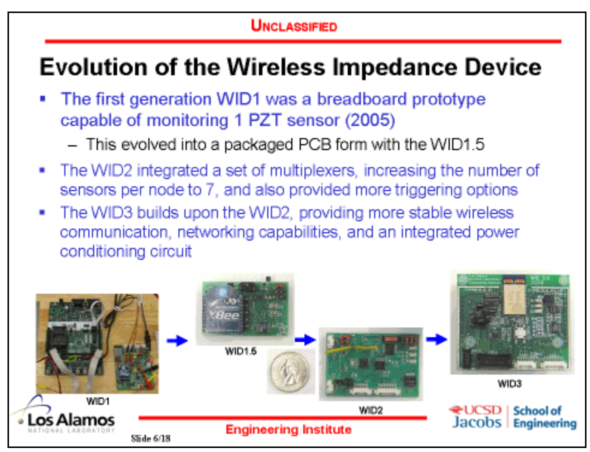


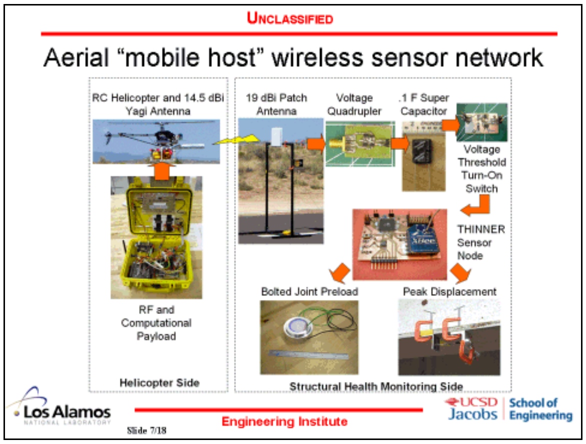






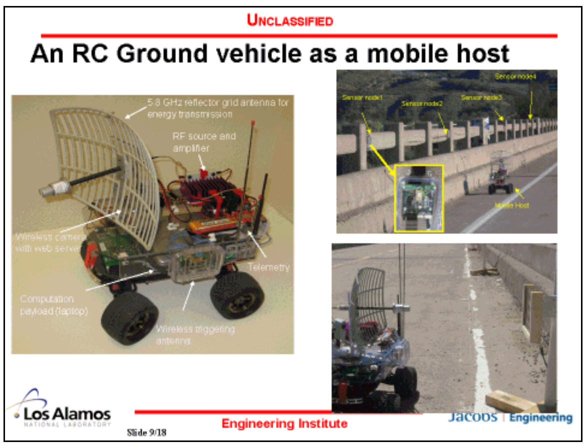




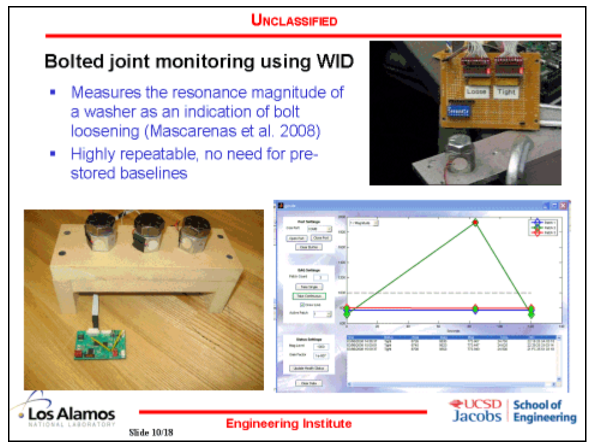


UNCLASSIFIED
Aerial "mobile host" wireless sensor network
RC Helicopter and 14.5 dBi Yagi Antenna
19 dBi Patch Antenna
Voltage Quadrupler
.1 F Super Capacitor
Voltage Threshold Turn-On Switch
THINNER Sensor Node
RF and Computational Payload
Bolted Joint Preload
Peak Displacement
Helicopter Side
Structural Health Monitoring Side
Los Alamos
Engineering Institute
UCSD Jacobs School of Engineering
Slide 7/18

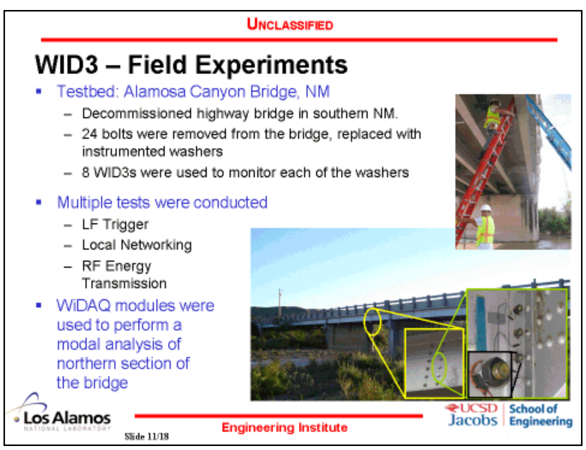
UNCLASSIFIED
Helicopter Movie and Test Results
Los Alamos
Engineering Institute
UCSD Jacobs School of Engineering
Slide 8/18



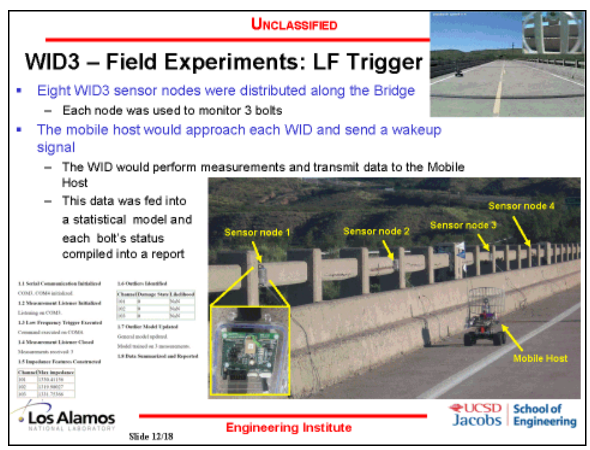
UNCLASSIFIED
An RC Ground vehicle as a mobile host
5.8 GHz reflector grid antenna for energy transmission
RF source and amplifier
Telemetry
Computation payload (laptop)
Los Alamos
Engineering Institute
Jacobs Engineering
Slide 9/18



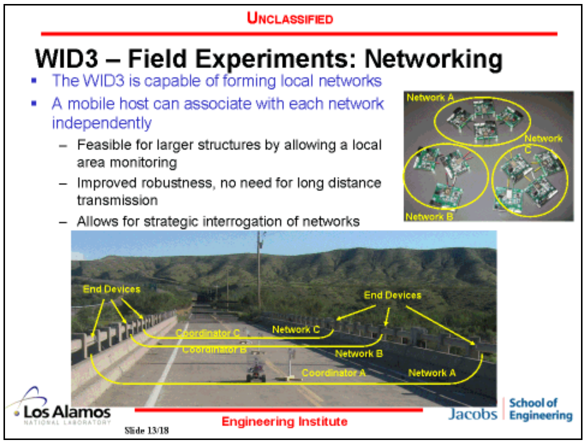
UNCLASSIFIED
Bolted joint monitoring using WID
Measures the resonance magnitude of a washer as an indication of bolt loosening (Mascarenas et al. 2008)
Highly repeatable, no need for pre-stored baselines
Loose
Tight
Los Alamos
Engineering Institute
UCSD Jacobs School of Engineering
Slide 10/18

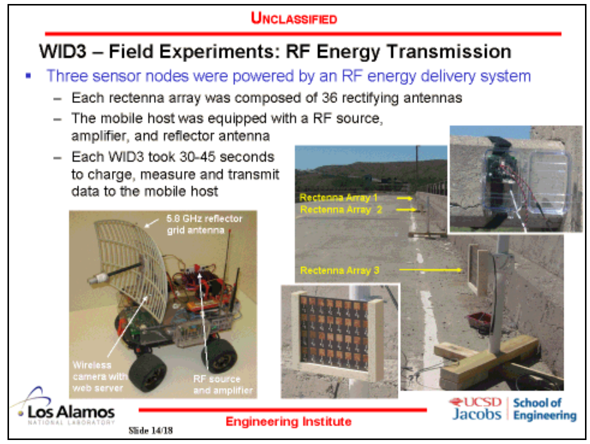


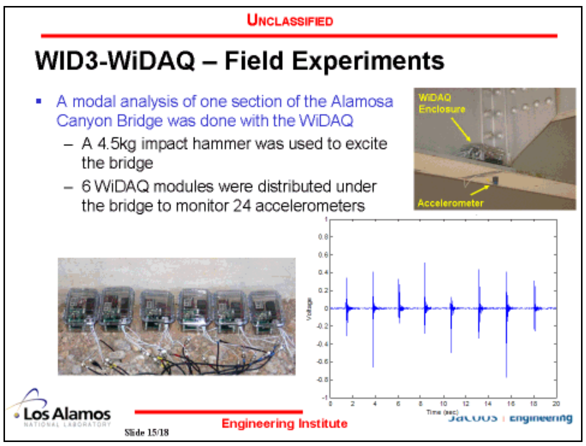
UNCLASSIFIED
WID3 – Field Experiments
Testbed: Alamosa Canyon Bridge, NM
Decommissioned highway bridge in southern NM.
24 bolts were removed from the bridge, replaced with instrumented washers
8 WID3s were used to monitor each of the washers
Multiple tests were conducted
LF Trigger
Local Networking
RF Energy Transmission
WiDAQ modules were used to perform a modal analysis of northern section of the bridge
Los Alamos
Engineering Institute
UCSD Jacobs School of Engineering
Slide 11/18

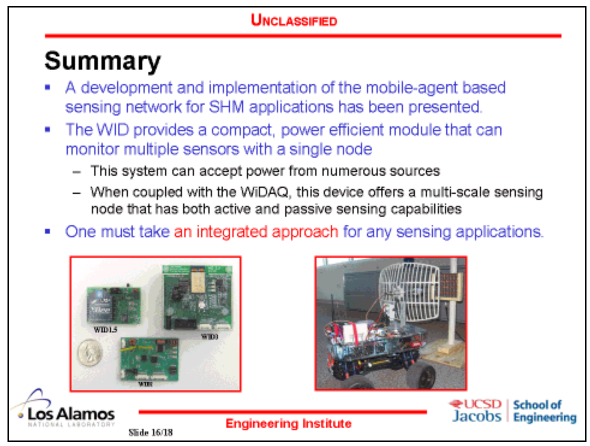


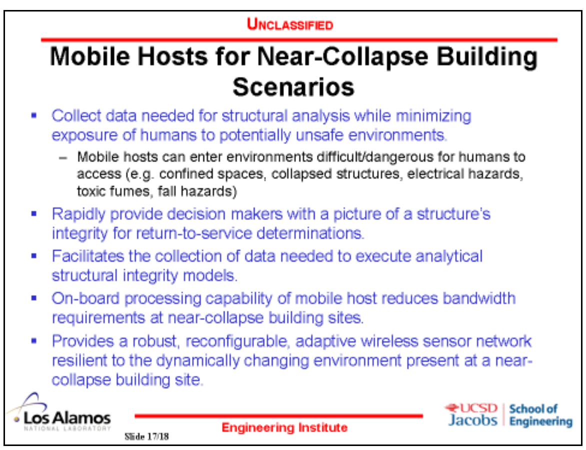
UNCLASSIFIED
WID3 – Field Experiments: LF Trigger
Eight WID3 sensor nodes were distributed along the Bridge
Each node was used to monitor 3 bolts
The mobile host would approach each WID and send a wakeup signal
The WID would perform measurements and transmit data to the Mobile Host
This data was fed into a statistical model and each bolt's status compiled into a report
Sensor node 1
Sensor node 2
Sensor node 3
Sensor node 4
Mobile Host
Los Alamos
Engineering Institute
UCSD Jacobs School of Engineering
Slide 12/18











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Robin Murphy

Dr. Robin Murphy is a Professor of Computer Science and Engineering and Director at the Center for Robot-Assisted Search and Rescue at Texas A&M. She has been an active researcher in rescue robotics since 1995, served with Florida Task Force 3 as a technical search specialist from 2001-2008, and has participated in the majority of known rescue robot deployments, including the first use of ground robots for search and rescue (World Trade Center collapse) and the first use of small unmanned aerial vehicles for search and rescue (Hurricane Katrina). She has over 100 scientific publications on rescue robots and related areas and serves on the National Academy of Engineering Studies and the Defense Science Board.

Use of Small Unmanned Ground and Aerial Vehicles for Structural Assessment and Reach-Back

This presentation describes the use of small ground and aerial robots by responders to i) collect post-disaster structural data and ii) reach-back to experts. The Center for Robot-Assisted Search and Rescue (CRASAR) has assisted with nine incidents, starting with the World Trade Center collapse in 2001. Three of those deployments focused on supporting structural assessment of buildings:

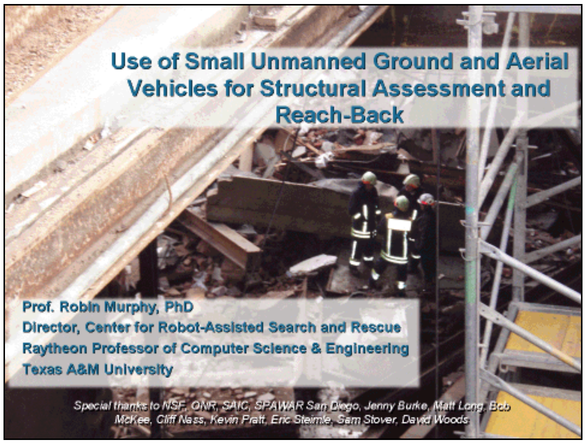
During deployment with Florida Task Force 3 at Hurricane Charley (2005), CRASAR showed the advantages of laser illuminators for more accurate assessment of building interiors in total darkness than with thermal cameras. The laser illuminator was originally designed for a ground robot but was used manually.

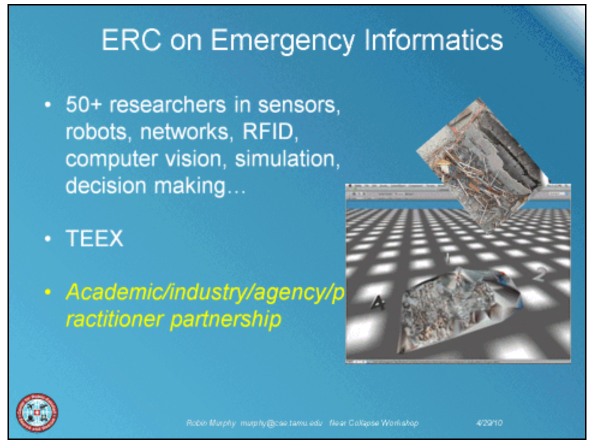
Under funding from the National Science Foundation, CRASAR used an aerial vehicle to document damage to multi-story commercial structures in Mississippi after Hurricane Katrina (2006). A four-person team including Sam Stover (Indiana Task Force 1) flew for 5 days mapping 10 structures over 30 flights. In addition to the practical expertise in operations, data was transferred each night to a team of disaster structural experts Bill Bracken (Florida State Emergency Response Team), Dave Hammond (FEMA), and Scott Nacheman (Indiana Task Force 1), plus a team of academic civil engineers including Doug Foutch (National Science Foundation), Sunil Saigal (University of South Florida), and Masanobu Shinozuka (UC Irvine) for evaluation. The reach-back efforts introduced significant deficits in situation awareness and general understanding.

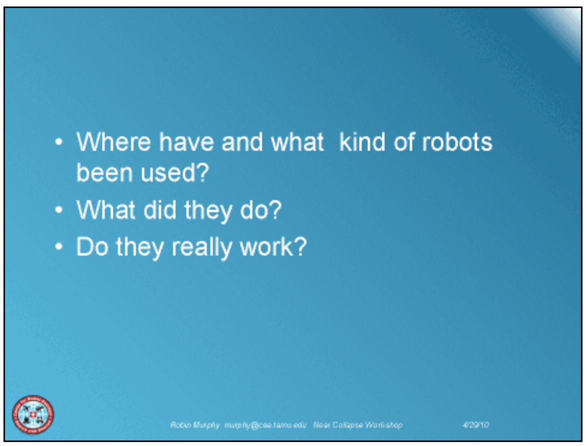
CRASAR assisted with structural forensics using ground and air robots at the 2007 Berkman Plaza II parking garage collapse in Jacksonville, Florida. Two types of ground robots were used to collect data: an active boroscope-like camera from Japan was used to penetrate between pancaked layers with less than an inch of clearance, while a small shoe-box sized robot entered the standing portion of the structure and documented sizable cracks. An aerial vehicle was used to document damage that a manned helicopter could not reach due to safety concerns and stirring up dust. Real-time interpretation of the data was subject to the same deficits seen at the post-Katrina survey.

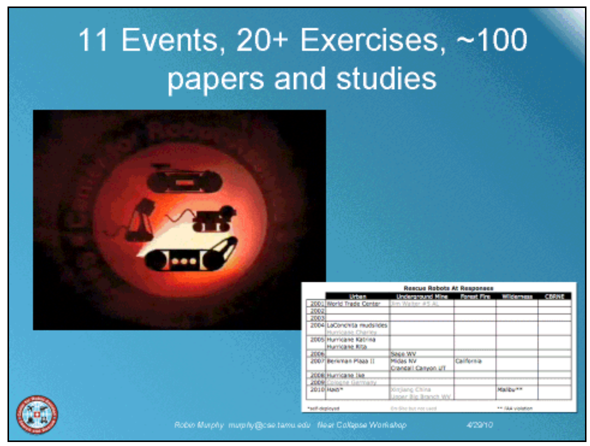
These experiences provide the community with concrete examples of how ground and aerial robots can be used, workable operational protocols, and suggestions for managing tele-engineering, including just-in-time training.

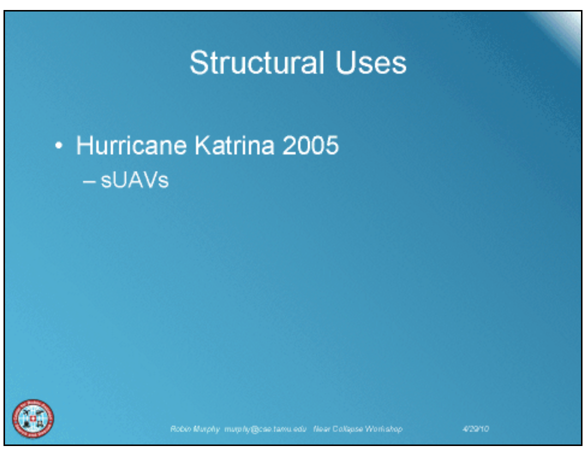
Presentation Slides

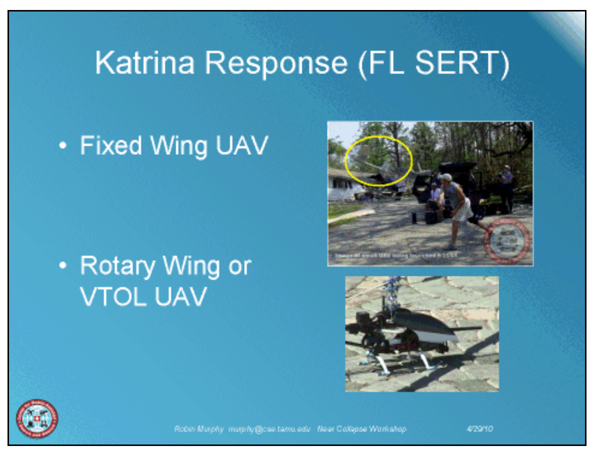




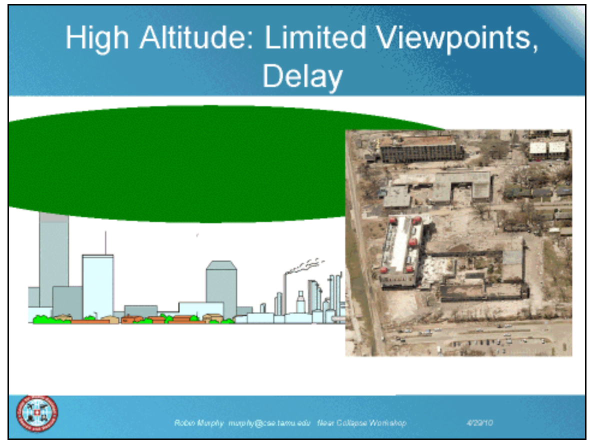




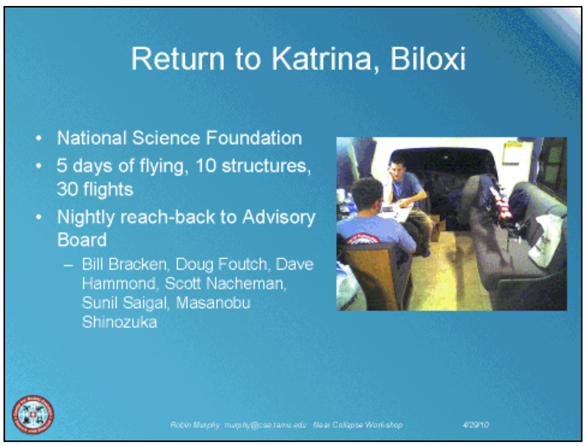




Video On Demand

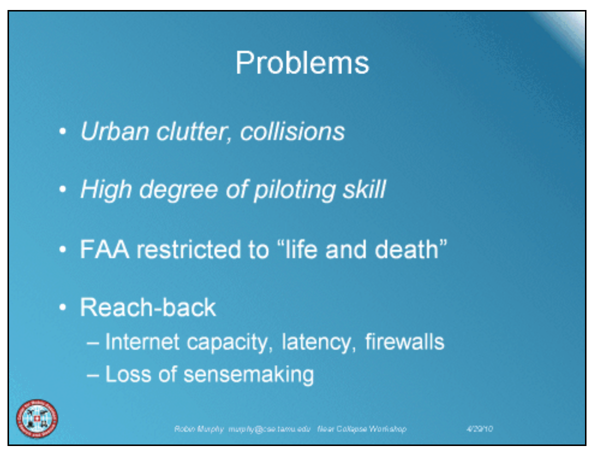


High Altitude: Limited Viewpoints, Delay



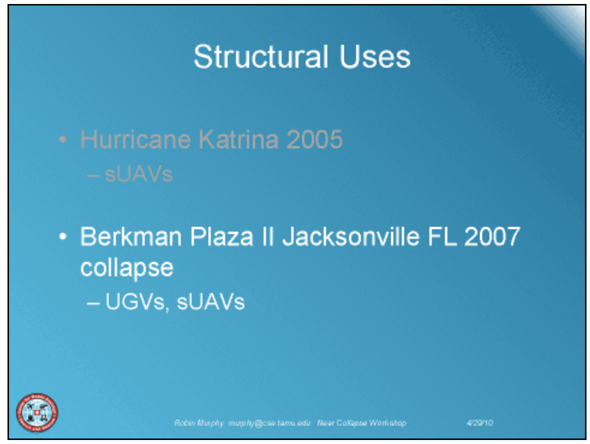
Return to Katrina, Biloxi
• National Science Foundation
• 5 days of flying, 10 structures, 30 flights
• Nightly reach-back to Advisory Board
– Bill Bracken, Doug Foutch, Dave Hammond, Scott Nacheman, Sunil Saigal, Masanobu Shinozuka

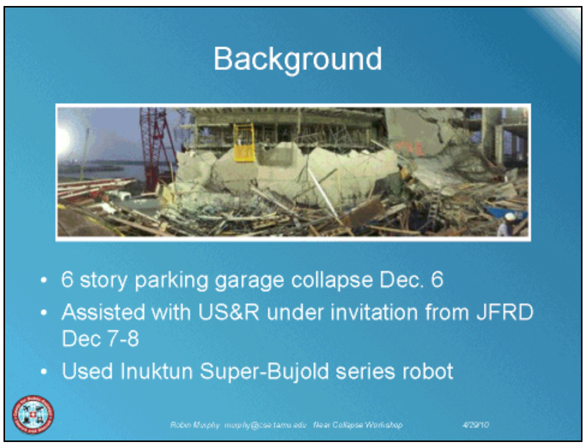
LIVE
CNN SURVEYING THE DAMAGE
SAUDI ARABIA'S KING ABDULLAH APPEALED TO MU



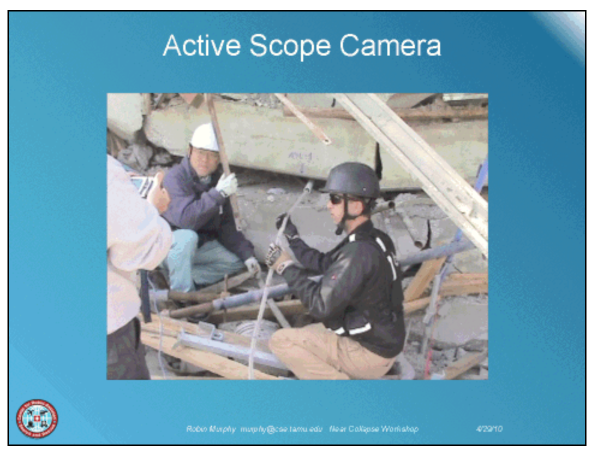
Problems
• Urban clutter, collisions
• High degree of piloting skill
• FAA restricted to "life and death"
• Reach-back
– Internet capacity, latency, firewalls
– Loss of sensemaking

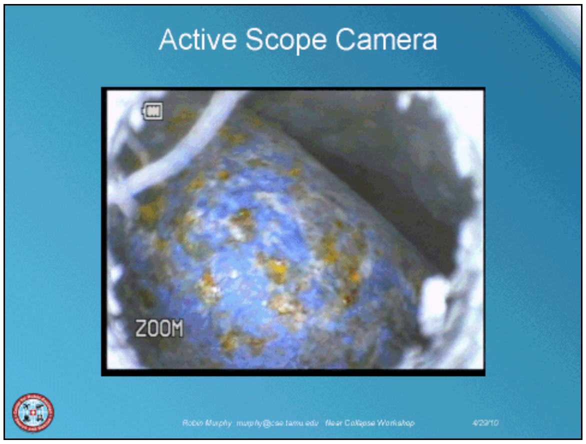

Example Labeling
CRASAR: Return to Katrina
C-side
Barges
hotel
B-side
D-side
Hard Rock Casino
A-side


Structural Uses
• Hurricane Katrina 2005
– sUAVs
• Berkman Plaza II Jacksonville FL 2007 collapse
– UGVs, sUAVs

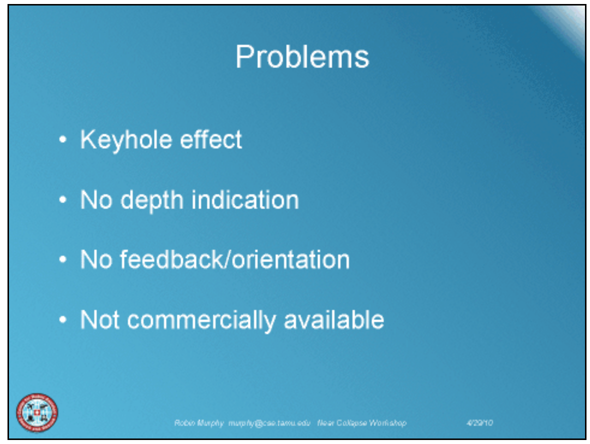

Background
• 6 story parking garage collapse Dec. 6
• Assisted with US&R under invitation from JFRD Dec 7-8
• Used Inuktun Super-Bujold series robot


Pitch: -46 deg Raise: 45 deg

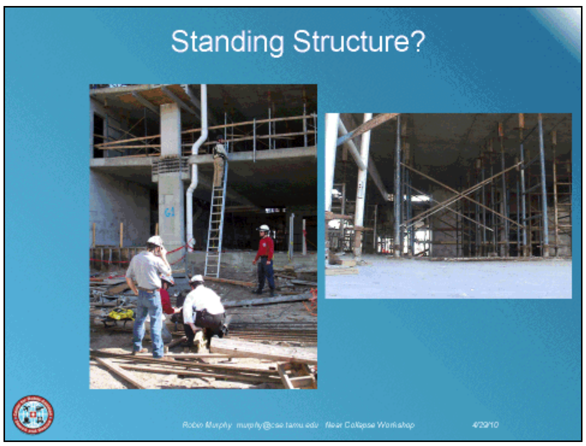

Active Scope Camera



Active Scope Camera
ZOOM

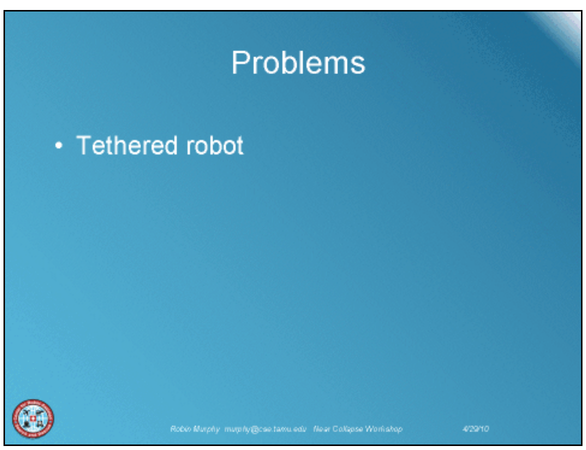


Problems
• Keyhole effect
• No depth indication
• No feedback/orientation
• Not commercially available

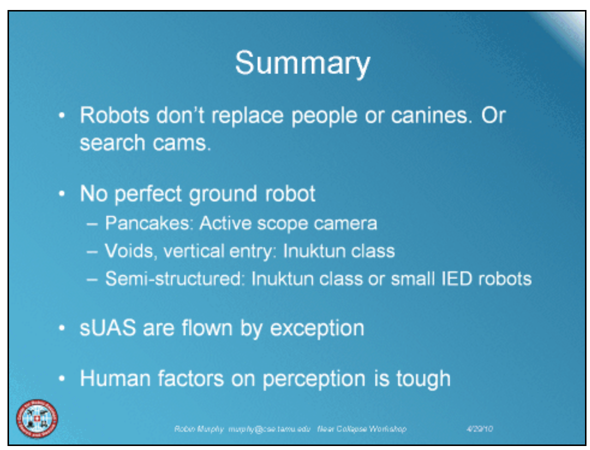


Standing Structure?

Sample Photos
Pitch: 1 deg Raise: 18 deg
Temperature: 37C Battery: 38.0 V
Pitch: 1 deg Raise: 18 deg
Temperature: 37C Battery: 37.9 V



Problems
• Tethered robot



Summary
• Robots don't replace people or canines. Or search cams.
• No perfect ground robot
– Pancakes: Active scope camera
– Voids, vertical entry: Inuktun class
– Semi-structured: Inuktun class or small IED robots
• sUAS are flown by exception
• Human factors on perception is tough

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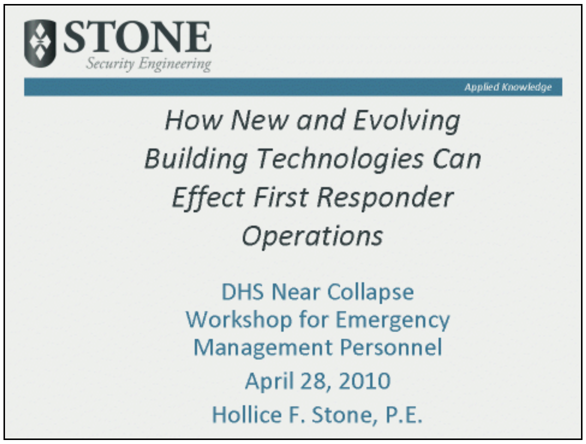
Hollice Stone

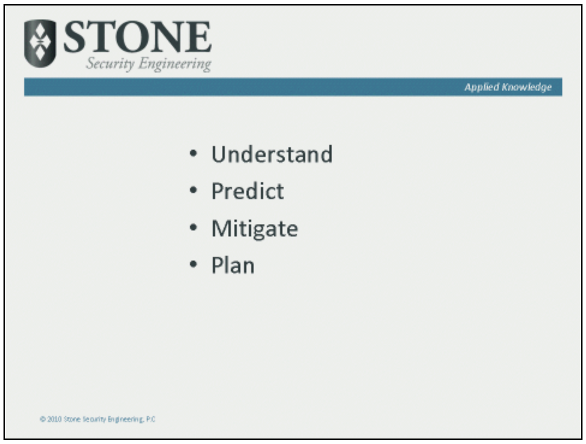
A bio of Ms. Stone can be found on page 53.

How New and Evolving Building Technologies Can Affect First Responders' Operations

As the design and engineering of buildings becomes more sophisticated and begin to incorporate more lightweight materials, sustainable design practices and blast and other security-related design enhancements, it is important to consider the effects of these new design practices on first responders and their emergency operations. This presentation discusses several building design elements (such as blast- and ballistic-resistant windows, post-tensioned structural systems) and how they can affect emergency response. The intent of this presentation is to inform researchers and designers as to first responder considerations that can be incorporated into their design and research efforts.

Presentation Slides

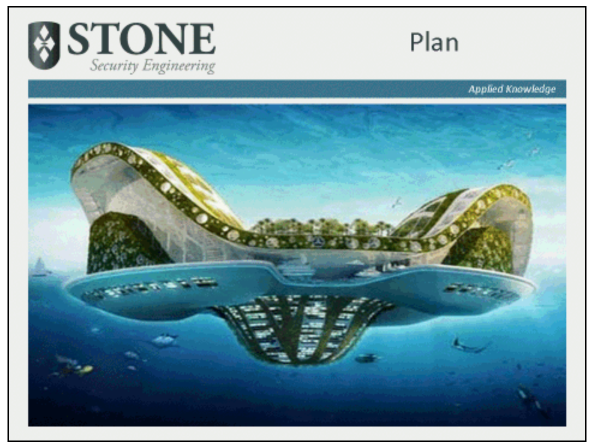




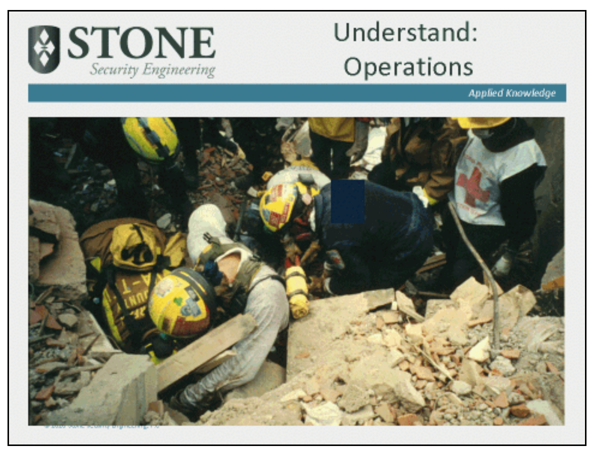

STONE
Security Engineering
Understand
Applied Knowledge


STONE
Security Engineering
Predict
Applied Knowledge


STONE
Security Engineering
Mitigate
Applied Knowledge


STONE
Security Engineering
Plan
Applied Knowledge

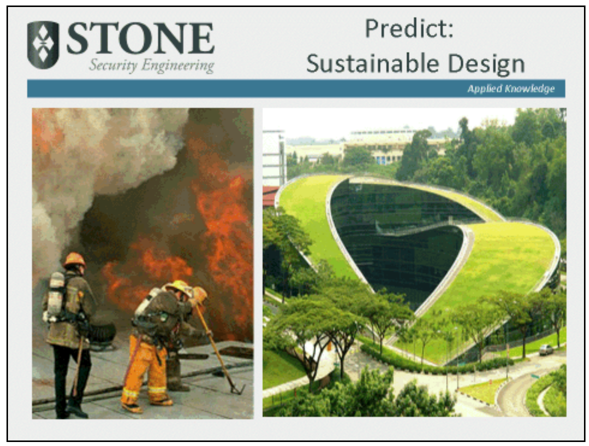

STONE
Security Engineering
Understand:
Operations
Applied Knowledge

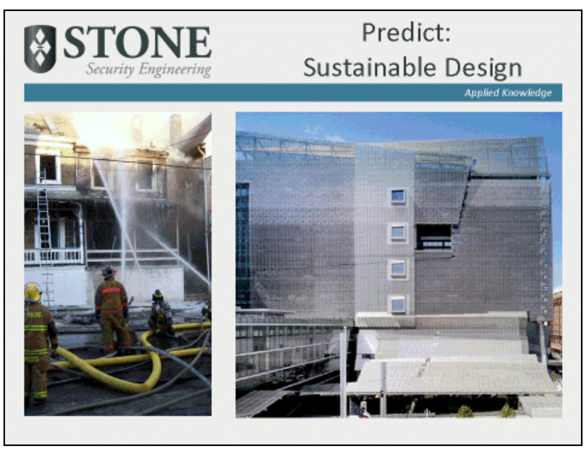

STONE
Security Engineering
Understand:
Operations
Applied Knowledge


STONE
Security Engineering
Understand:
Operations
Applied Knowledge

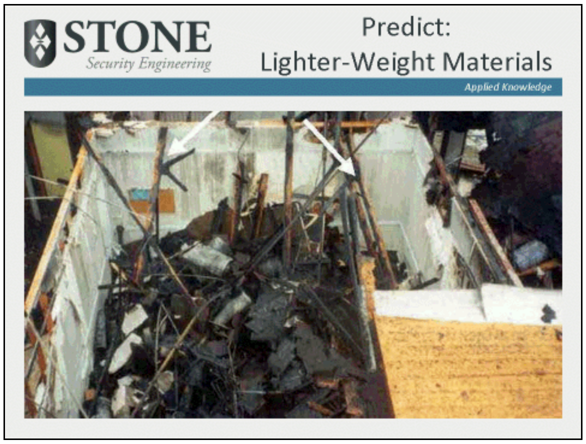

STONE
Security Engineering
Predict:
Sustainable Design
Applied Knowledge


STONE
Security Engineering
Predict:
Sustainable Design
Applied Knowledge


STONE
Security Engineering
Predict:
Sustainable Design
Applied Knowledge


STONE
Security Engineering
Predict:
Sustainable Design
Applied Knowledge


STONE
Security Engineering
Predict:
Lighter-Weight Materials
Applied Knowledge



STONE
Security Engineering
Predict:
Lighter-Weight Materials
Applied Knowledge

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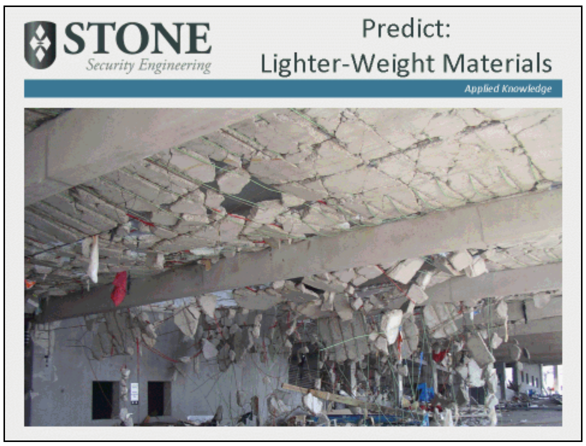
Security Engineering
Predict:
Lighter-Weight Materials
Applied Knowledge



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Security Engineering
Predict:
Lighter-Weight Materials
Applied Knowledge

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Security Engineering
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STONE
Security Engineering
Predict:
Blast and Security
Applied Knowledge

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Predict:
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Applied Knowledge

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Security Engineering
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Blast and Security
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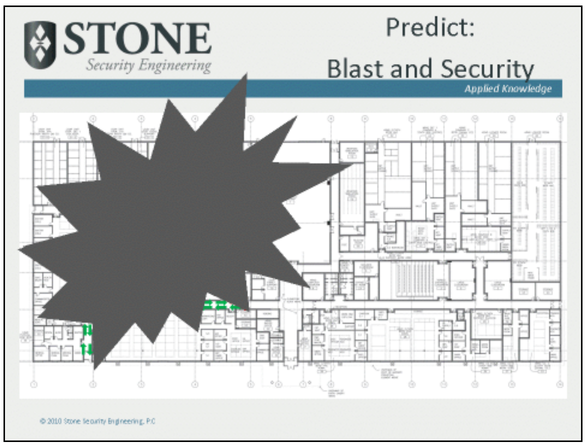
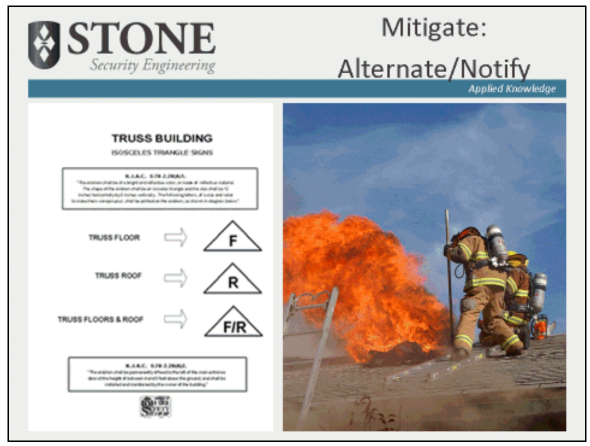


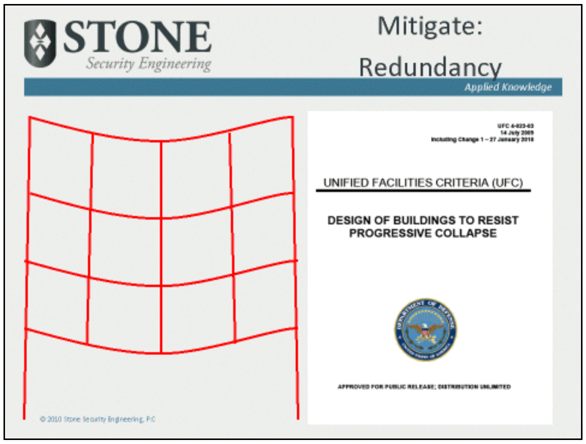
STONE
Security Engineering
Predict:
Blast and Security
Applied Knowledge

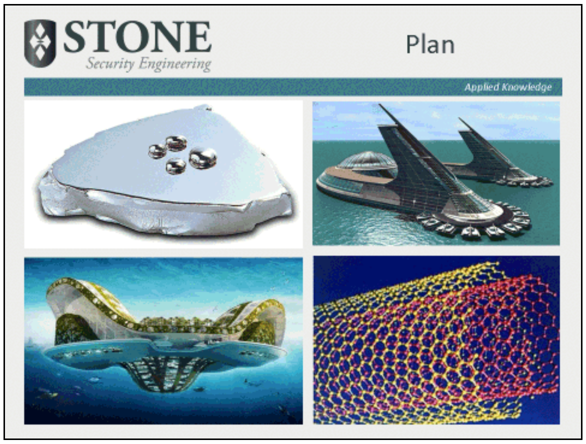


STONE
Security Engineering
Mitigate:
Alternate/Notify
Applied Knowledge
TRUSS BUILDING
ISOSCELES TRIANGLE SIGNS
TRUSS FLOOR
F
TRUSS ROOF
R
TRUSS FLOORS & ROOF
F/R

STONE
Security Engineering
Mitigate:
Re-Design
Applied Knowledge

STONE
Security Engineering
Mitigate:
Awareness/Training
Applied Knowledge
GSA Sponsored
Firefighter Ingress/Escape
Procedures and Training
for Security Window Systems
Module 1 – Introduction and
Background





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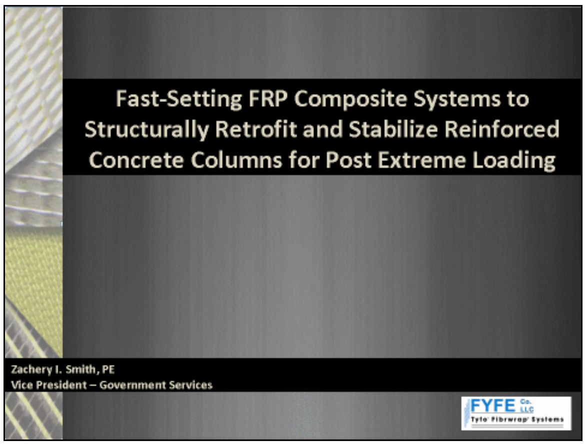
Zach Smith

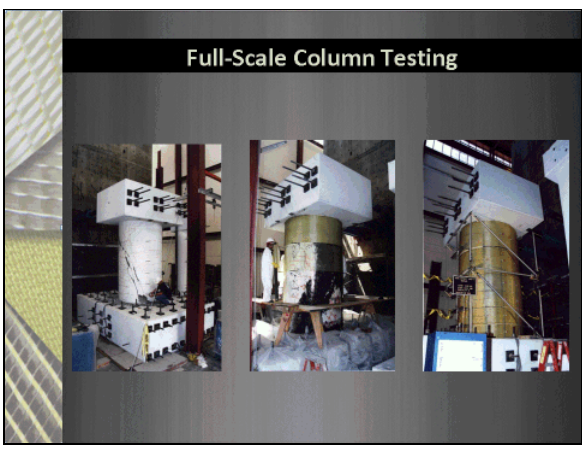
Zach Smith graduated of Cal Poly, San Luis Obispo with a bachelor of science degree in Civil Engineering and has been with Fyfe Company since 2003. He now serves as the Government Services lead for the Fyfe Company – developing blast mitigation and force protection solutions for a wide variety of projects. Mr. Smith is continually immersed in new research efforts for blast mitigation throughout North America with universities, agencies, and independent companies and encourages interested parties to contact him on the subject. He is a registered professional engineer in the State of New York.

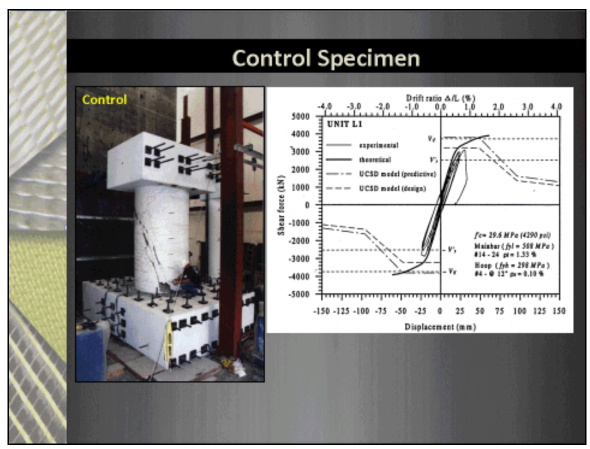
Fast-Setting FRP Composite Systems to Structurally Retrofit and Stabilize Reinforced Concrete Columns for Post-Extreme Loading

This presentation illustrates tested methods to stabilize structures damaged from extreme loading events such as fire, impact, blast, earthquakes etc. using fast-setting FRP composites to wrap structural elements. Recently, completed testing has used glass and carbon fabrics with special fast-setting epoxy resins that can be cured within 48 hours. Control specimens were compared against near-collapse specimens damaged via shake tables before and after fiberwrapping. Moderate crack repairs were completed with fast-set non-shrink repair mortars. Phase one test results indicated that full strength and drift capacity were restored with the use FRP composites. The next proposed phase of testing will incorporate accelerated curing epoxies using ultra-violet lights—bringing cure times within minutes. In the past the highly desirable characteristics of FRP composites such as high-strength, light-weight, and ease of installation with no "hot-work" or heavy impact tools have been overshadowed by their relatively slow cure times. With the epoxy cure time enhanced by magnitudes of order, FRP composites could be some of the best suited emergency repair materials.

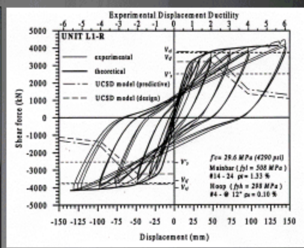
Presentation Slides







Damaged and then retrofitted specimen



1/4 Scale 2-Span Bridge Tested UNR

Highest Repairable Damage Level

Highest Repairable Damage Level

- Max Drift Ratio: 10.4%
- Max Longitudinal Bar Strain: 72000 με (30 times the yield strain)
- Max Spiral Strain: 1400 με (74% of yield)

Repair Design

- Restoring confinement
  Spiral contribution is neglected inside plastic hinge. Providing 300 psi confinement pressure inside the plastic hinge (1.5D) at a radial dilating strain of 0.004.

- Shear strength restoring
  Spiral and concrete contribution are neglected inside the plastic hinge.
  No contribution for concrete and 100% contribution for spirals outside the plastic hinge

- 2 layers CFRP inside plastic hinge (1.5D), and 1 layer outside.

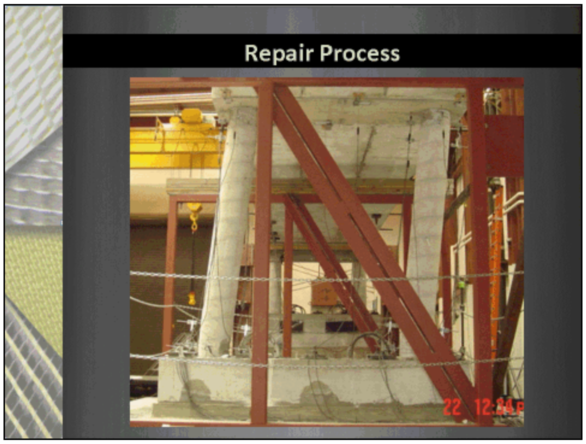
Jacketing Properties
Fyfe Co. Tyfo® SCH-41 / Tyfo ® S Epoxy System

Design
E=8925 ksi
Tensile strength=100 ksi
Rupture strain=0.012
Laminate t = 0.04"

Design properties are based on one week regular curing.

54 hr cure (Actual)
E=8292 ksi
Tensile strength=89 ksi
Rupture strain=0.01
Laminate t = 0.04"

Actual properties are achieved after 54 hours curing.

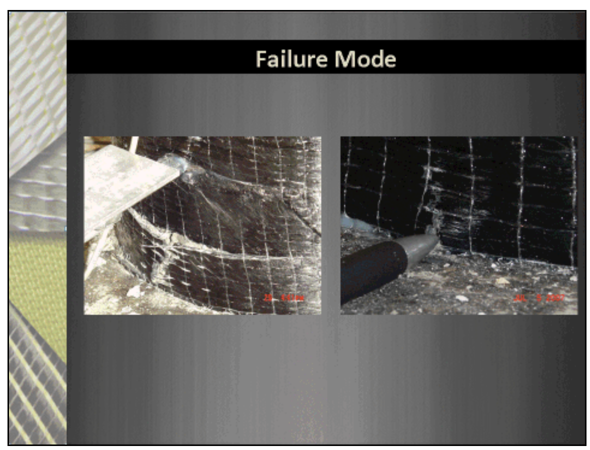

Repair Process

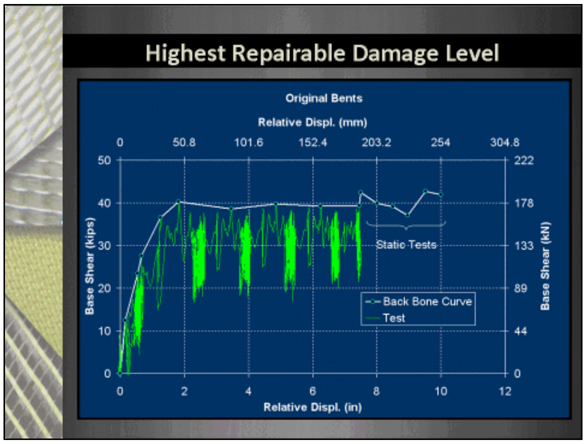

Repair Process

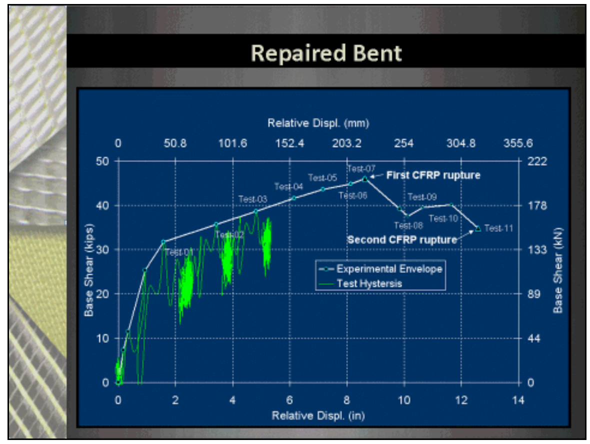

Repair Process

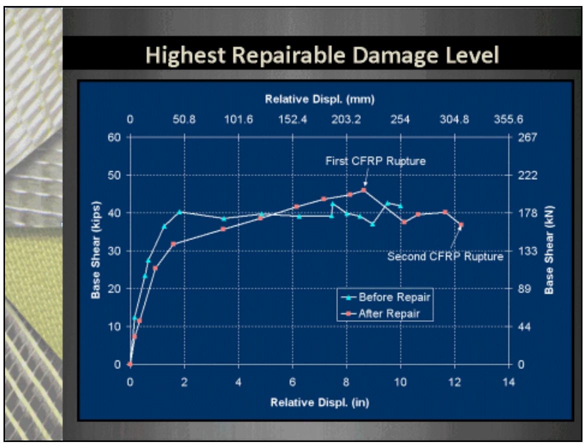

Repair Process

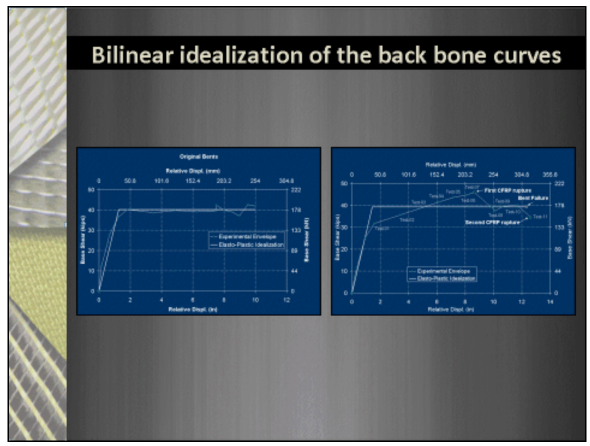

Repair Process

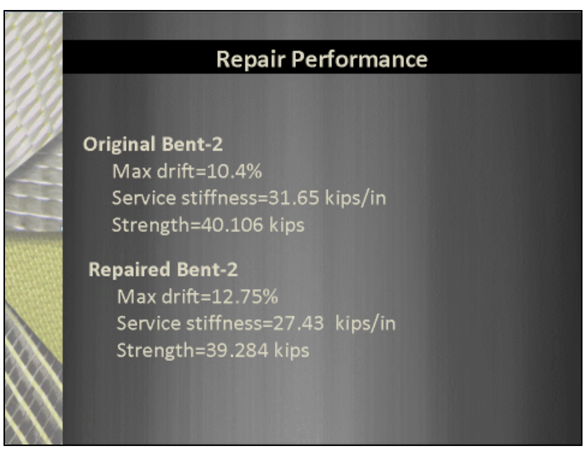

Failure Mode

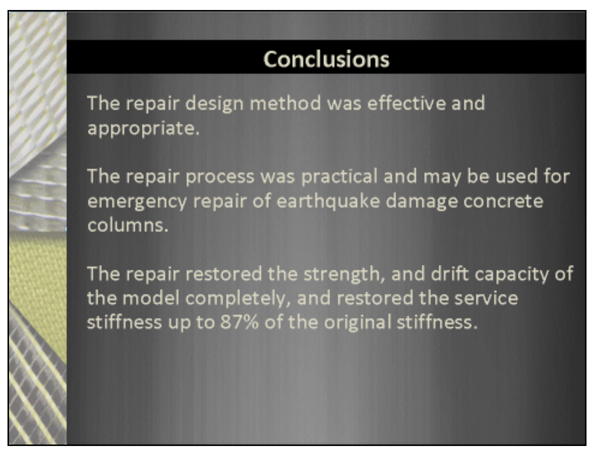

Highest Repairable Damage Level
Original Bents
Relative Displ. (mm)
Base Shear (kips)
Base Shear (kN)
Static Tests
Back Bone Curve
Test
Relative Displ. (in)

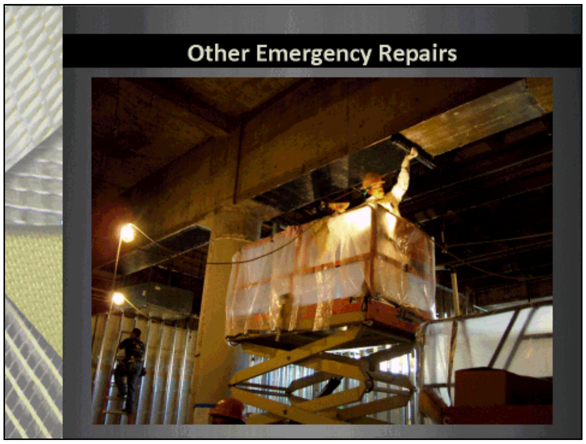

Repaired Bent
Relative Displ. (mm)
First CFRP rupture
Second CFRP rupture
Experimental Envelope
Test Hysteresis
Base Shear (kips)
Base Shear (kN)
Relative Displ. (in)

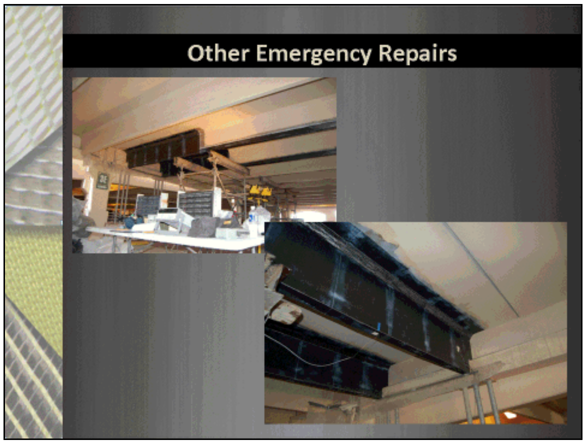

Highest Repairable Damage Level
Relative Displ. (mm)
First CFRP Rupture
Second CFRP Rupture
Before Repair
After Repair
Base Shear (kips)
Base Shear (kN)
Relative Displ. (in)


Bilinear idealization of the back bone curves


Repair Performance
Original Bent-2
Max drift=10.4%
Service stiffness=31.65 kips/in
Strength=40.106 kips
Repaired Bent-2
Max drift=12.75%
Service stiffness=27.43 kips/in
Strength=39.284 kips


Conclusions
The repair design method was effective and appropriate.
The repair process was practical and may be used for emergency repair of earthquake damage concrete columns.
The repair restored the strength, and drift capacity of the model completely, and restored the service stiffness up to 87% of the original stiffness.





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Thomas Attard

Dr. Thomas Attard received his Ph.D. from Arizona State University in 2003 from the Department of Civil and Environmental Engineering. His research areas include structural dynamics, earthquake engineering, computational simulations/software development, material mechanics, and advanced composites. His research covers both computational/analytical and experimental areas, and he was also the director of a seismic testing facility for large-scale civil structures. Dr. Attard designed and managed the Center for Earthquake Modeling and Simulations for 3 years at California State University, Fresno, before accepting a position at The University of Tennessee, Knoxville, starting in Fall 2009.

Dr. Attard was also the Chairman of the 10th Pan American Congress of Applied Mechanics (PACAM X) in 2008 in Cancun, Mexico, and was also the North American chairman of PACAM XI in Foz do Iguacu, Brazil.

Development of a New Lightweight 'Rubberized-Carbon' Composite for New or Already-Damaged Structures

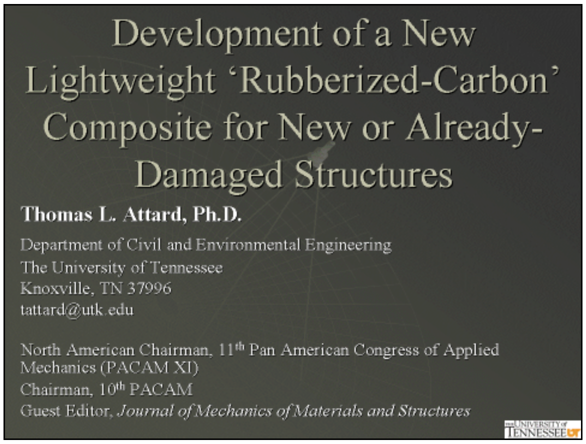
CarbonFlex is a new generation of advanced protection super-composite material developed to mitigate structural and nonstructural damage by combining a high-strength/highly stiff material with highly efficient energy dissipation and ductility.

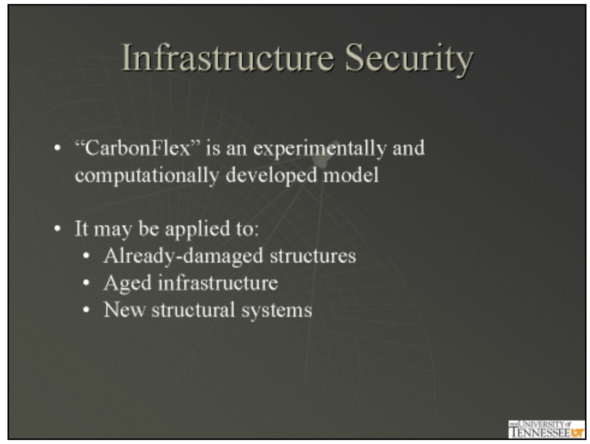
The *goal* in developing CarbonFlex is to integrate viscoelastic behavior that transitions to a purely sustainable elastomeric state via sustainable interfacial interaction between the composite material and the underlying substrate that it protects.

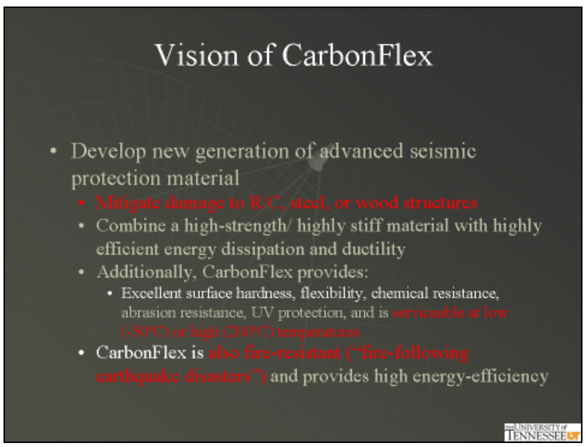
The *strategy* for implementation involves ensuring interfacial bonding with the exterior substrate. The *outcome* is a newly integrated 'carbon-rubber' product used to protect non-structural and structural components in various structures, including wood-frame homes, and reinforced concrete and steel structures, subjected to various dynamic loads, including blast and seismi loads. CarbonFlex provides binding stiffness to new or already-damaged structures to reduce displacement and provides ductility and energy dissipation in order to reduce accelerations and subsequent non-structural damage. Preliminary tests of wrapped 2x4 wood beams indicate that CarbonFlex increases displacement ductility and energy dissipation by 100% compared to using carbon-fiber reinforced polymer (CFRP) wrapping alone. The interfacial bond interactions between the CarbonFlex constituents, and also between CarbonFlex and the substrate ensures continued strength and energy dissipation and protection. The interfacial interaction is key for identifying transition zones such as strain hardening, stress-recovery, creep, and stress relaxation under tensile, compression, bending, torsional, and axial-torsional loading.

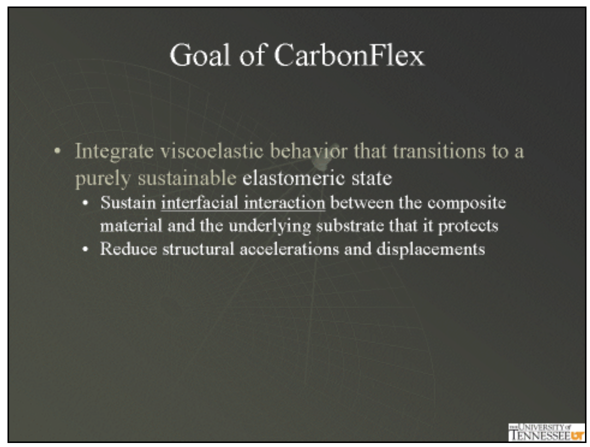
CarbonFlex provides fire resistance and has viscoelastic and elastomeric properties providing elongation of 480%. It alleviates problematic rigid-to-rigid compatibility issues between the substrate and the CarbonFlex through stress-relaxation in the CarbonFlex composite that enables adjacent unwrapped substrates to continue being loaded and not experience deterioration from non-usage. The interfacial interaction that exists between the CarbonFlex and the substrate enables protected wrapped substrates to be loaded. This includes protection of wood homes and already-damaged reinforced concrete and steel structures, such as bridges and tunnels. The strength and flex of the material are adjustable depending on the desired needs during application. Environmentally, CarbonFlex has no out-gassing (while remaining compliant with usage in food areas). It has zero volatile organic compounds; it is UV protected; and it remains flexible at low temperatures. It is crack-resistant under high flex conditions and is serviceable at either low (-50ºC) or high (200ºC) temperatures while offering water/moisture resistance and finally providing energy/insulation efficiency to homes with an R28 R-rating.

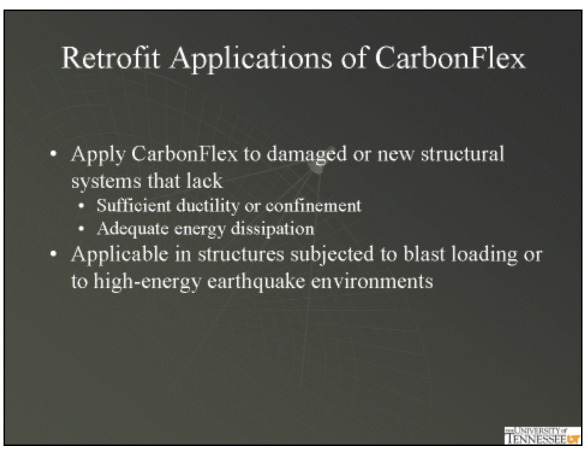
Presentation Slides

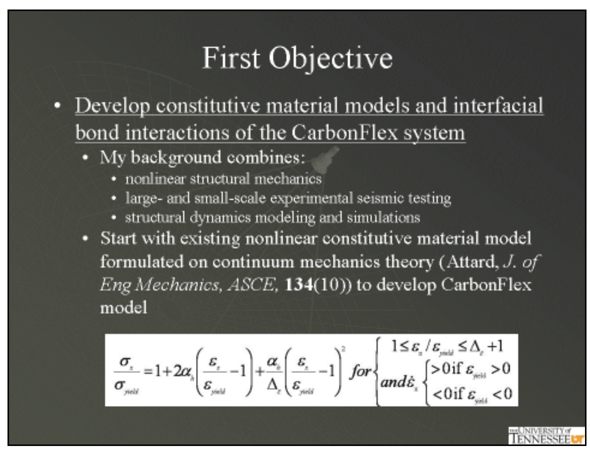












First Objective, cont.

- The CarbonFlex model will be a function of:
  - Material strength and nonlinear stress-strain behavior
  - Intrefacial bond interactions between the fire-resistant intumescent polyurea and the carbon-fiber constituents and also CarbonFlex and the substrate
    - Examine critical bond-slip conditions to identify transition zones
      - Strain hardening
      - Stress recovery
      - Stress relaxation and creep
  - Viscoelastic & purely elastomeric properties of CarbonFlex
  - We tested load coupons under tension, compression, bending, torsion, and axial-torsion

Second Objective

- Assess the feasibility of applying CarbonFlex in already-damaged structures as a function of:
  - The elastomeric polyurea thickness
  - For new structures, reduction in how much substrate material is needed (such as R/C or wood)
  - Any openings in the substrate that could affect cost, binding stiffness, ductility, energy dissipation, and ultimately the ability to reduce displacements and accelerations

Third Objective

- Calculate global responses and local constitutive behaviors of protected substrates
  - Perform computational simulations that incorporate embedded constitutive CarbonFlex models
  - Use previously-developed simulation codes with embedded highly nonlinear constitutive models. See:
    - Attard, Engineering Structures, 29(8)
    - Attard, J. Structural Engineering, ASCE, 133(9)
  - Determine response time-histories and hystereses

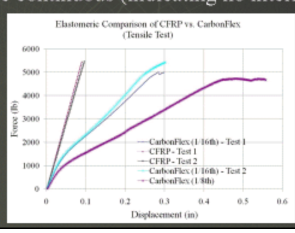
Preliminary Results

- CarbonFlex is unique from other substrate reinforcing materials
  - Constitutively combines high-strength, high-energy dissipation, and fire-resistivity
  - Shows no signs of constituent debonding
  - Tests shows tremendous shear strength and energy dissipation abilities
    - 100% increase in ductility and energy dissipation compared to using carbon fibers

Preliminary Tensile Coupon Results

CFRPs (FRP cloth, 0.068 in. thick x 1 in. wide) vs. CarbonFlex (0.19 in. x 1 in. and 0.32 in. x 1 in.)

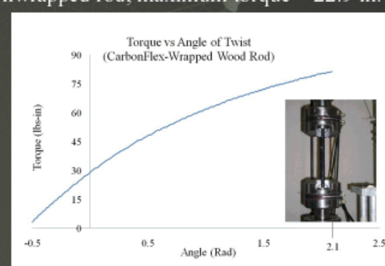
- Displacement of CarbonFlex coupon is 3.75 larger
  - It is 6.25x larger using a thicker CarbonFlex and 3.5x larger than CFRP yield
- Curves are continuous (indicating no interfacial slip)



Preliminary Torsion Coupon Results

CarbonFlex (12-in. long White Pine Wood, ½ in. diameter)

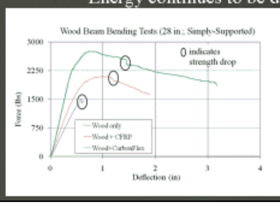
- Maximum torque = 80.9 in.-lb
- Unwrapped rod, maximum torque = 22.9 in.-lb



Preliminary Bending Coupon Results

CarbonFlex (28 in. span, simply-supported, 2x4 wood beam, center load)

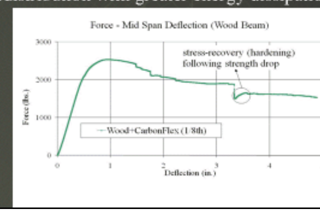
- Significant increase in displacement, shear strength, and energy dissipation
  - Over 100% increase compared to CFRP-wrapped beam
  - CarbonFlex holds damaged beam even after strength drop
    - Loads re-distributed to the wrap
    - Energy continues to be dissipated



Preliminary Bending Coupon Results

CarbonFlex (thicker base)

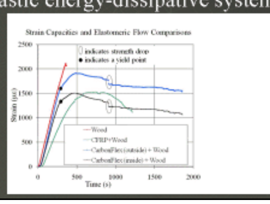
- Strength drop followed by recovery stress (hardening) due to the viscoelastic nature of CarbonFlex and interfacial interaction
  - Thicker polyurea offers greater support to the carbon fiber upon load redistribution with greater energy dissipation and ductility



Preliminary Bending Coupon Results

CarbonFlex (thicker base)

- 'Parallel' strains on substrate and CarbonFlex interfaces
  - No signs of debonding
- Negligible strain rate
  - No deformation in the amorphous polyurea
  - Purely elastomeric system following strength drop
  - Viscoelastic energy-dissipative system after yield

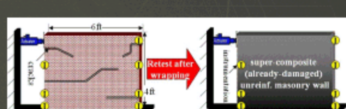


Applications

- Wrapping new or already-damaged structures
- We are currently making CarbonFlex fibers embedded in concrete
- Liquid CarbonFlex for aggregate coating to reduce cracking in concrete
- Ballistics and blast resistance
  - Protected armored transport and weapons vehicles
  - Protective vest skins
- Bio-medical applications
  - Prosthetics
- Wood homes
  - Increase energy efficiency to R28 (vs R11 fiberglass)

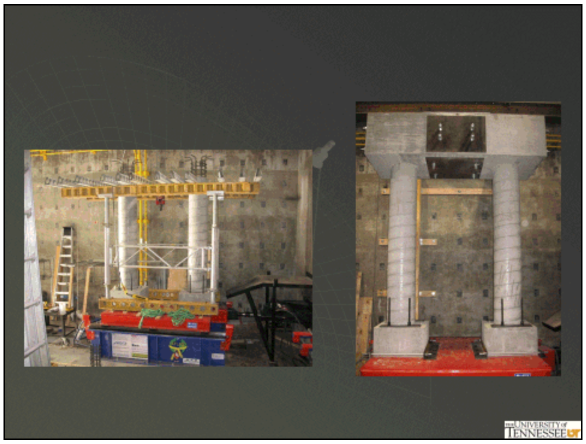
Applications - Haiti

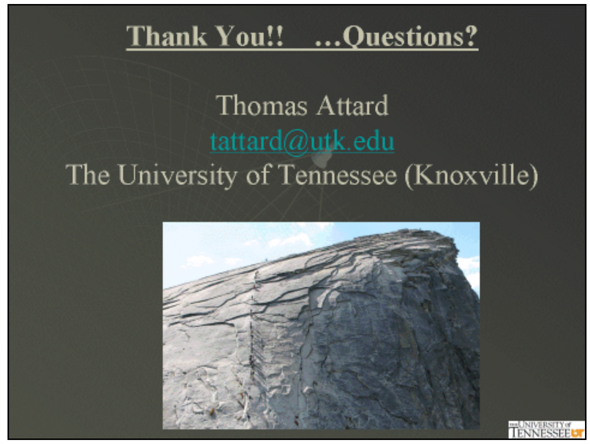
- Wrapping substandard damaged structures
- Strength and energy dissipation should be larger than pristine systems designed according to code



Conclusions

- Development of a new interfacially interacted composite material for damage mitigation of new and already-damaged structures
  - Provides tremendous increase in energy dissipation and ductility
  - Provides fire-resistance
  - Ideal for high-energy applications, including blast environments
- Upcoming tests:
  - Experimental shaking table tests and coupon testing




Thank You!! …Questions?
Thomas Attard
tattard@utk.edu
The University of Tennessee (Knoxville)

Mila Kennett

Milagros Kennett is a senior program manager in the Infrastructure and Geophysical Division (IGD) of the Science & Technology Directorate, U.S. Department of Homeland Security. Currently, she manages several projects of the DHS S&T Counter IED Research Program and is responsible for the all IGD International Programs and activities. She is also in charge of a number of workshops to position the vision and goals for the division to support infrastructure resiliency and the infrastructure of the future with underlying principles of national continuity, energy, environmental sustainability, and resiliency. Ms. Kennett has more than 15 years of experience on projects in the Middle East, Asia, Latin America, Europe, and the United States. Her main focus has been on natural and manmade disaster mitigation; building security; risk assessments; and urban development. She was formerly Deputy Director of the Ministry of Public Works in the Dominican Republic and served as Dean of the School of Architecture and Engineering at the Centro de Estudios Tecnológicos. Ms. Kennett has been awarded and conducted large research projects for the U.S. National Science Foundation. She was the staff Architect of the Mitigation Branch of FEMA/Department of Homeland Security. She created and managed the Risk Management Series, which are a series of publications devoted to natural and manmade disasters. The Risk Management Series publications are intended to minimize conflicts that may arise from a multihazard design approach and to develop multihazard risk assessments methodologies for buildings exposed to chemical, biological, radiological, and explosive attacks as well as to earthquakes, floods, and high-winds. Ms. Kennett received a degree in architecture and urban design from the Universidad Autonóma de Santo Domingo and a master of arts degree in international development with a major in urban economics from American University in Washington, D.C.

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Tom Coleman

Thomas Coleman is the Infrastructure Protection Product Lead for the Transportation Security Laboratory (TSL), which is a Federal Laboratory assigned to the Headquarters of the Science & Technology Directorate, U.S. Department of Homeland Security. Mr. Coleman oversees research, testing, and product development in the areas of blast protection and durable building materials. Prior to assignment to TSL, he was a Director of Operations Research for Battelle, Managing Director for EGG Professional Services, and an active duty Air Force officer with field experience securing Departments of State and Defense installations in Europe. He holds a bachelor's degree from the State University of New York, Stony Brook, a master of science from University of Southern California, and is a graduate of the Air War College. He is a retired Lieutenant Colonel, U.S. Air Force Reserve.

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Eric Letvin

A biography of Mr. Letvin can be found on page 6.

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Mohammed Ettouney
A biography of Dr. Ettouney can be found on page 7.

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Hollice Stone
A biography of Ms. Stone can be found on page 53.

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Robert Hall

Dr. Robert Hall is currently a Principal Engineer with Engineering Innovations, LLC. Dr. Hall had previously served as the Division Chief, Geosciences and Structures, Engineering and Research Center, U.S. Army Corps of Engineer (USACE), 2001-2009, (Retired from USACE after 38 years of service). He has conducted research in the following areas: weapons and explosion phenomenology including airblast, fragmentation, projectile penetration, ground shock, cratering, and ejecta; material development and characterization, material modeling of composites, concrete and geologic materials; theoretical and computational structural mechanics and dynamics as it relates to response of conventional and protective structures subjected to both conventional and non-conventional weapons effects. Research in these focus areas produces technologies through the prediction of dynamic loads in a complex blast environment (internal and external detonations, shielding effects from barriers and building), pre- and post-failure structural response (including progressive structural collapse for a wide variety of structural types), hazards to personnel from airblast and debris, and expedient design/retrofit methods for increased survivability, including structural hardening. The advancement of the use of high-performance computing to simulate blast loading and structural response, the application of indigenous construction materials and lightweight advanced composite materials, and the development of expedient survivability procedures are an integral part of his research program. Expertise in structural dynamics has resulted in conducting research in the area of seismic response of concrete dams and hydraulic structures. In 2007, was invited by the Director of the "Autoridad del Canal de Panamá" (ACP) to Chair an Advisory Board to formally provide technical advice on a wide spectrum of issues related to the analysis, evaluation, and assessment of the seismic performance of the Canal's hydraulic structures. Hall received his PhD. from Oklahoma State University in 1985. He received his MSCE from Mississippi State University in 1978 and his BSCE from Auburn University in 1971.

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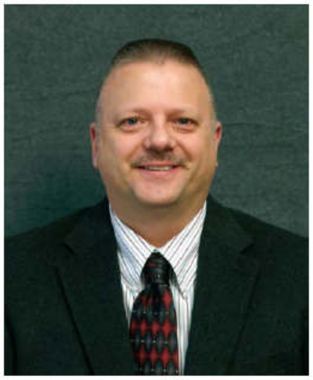
Bob McKee



J. Robert (Bob) McKee is a former Fire Chief–Paramedic from Clark County, Ohio. He was responsible for all administrative and emergency operations. During his 17 years he was responsible for countless incidents large and small. He was a Task Force Leader with Ohio's Urban Search and Rescue Team—Ohio Task Force One. Bob also worked as the special project's coordinator with his County Emergency Management Agency and he was the point of contact to Wright-Patterson Air Force Base in Dayton, where the Task Force was based. He was an Exercise Evaluation Technician (EET) for the Inspector General's Office on base.

Currently Bob is Director of Emergency Response and Rescue for the Texas Engineering Extension Service/US&R Division. He also serves as the Sponsoring Agency Chief for Texas Task Force One Urban Search and Rescue responding within the State and nationally as requested. Bob serves as a Point of Arrival/Mobilization Specialist for the Federal Emergency Management Agency (FEMA) Incident Support Team (IST), a past member of both the FEMA Logistics Working Group and the FEMA Training Working Group. Bob is a member of the IAB (Interagency Board) serving on the ICIS sub-committee.

Throughout his career, Bob has been involved in hands-on and on-site training situations addressing a variety of technical issues in emergency response and emergency response planning. In conjunction with his interest in business, Bob's practical experience with the Incident Command System (ICS) has provided him an understanding of structure and management. Bob is also certified on a variety of emergency response equipment. He is a certified and nationally credentialed instructor in several areas of emergency response.

Bob has had several State and Federal deployments during his tenure—tornados, floods and natural disasters as well as being deployed to the World Trade Center Collapse, Salt Lake City Olympics, Shuttle Columbia Disaster and Hurricanes Katrina, Rita and Hurricane Ike.

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Peter Keating

A bio of Mr. Keating can be found on page 60.

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Jeffrey Bolich

Jeffrey Bolich is the Technology Manager for the TEEX US&R Response Technology Program, which provides testing, assessment and analysis of emergency response equipment. Jeffrey comes from the petro/chemical industry where he has over 10 years of safety, health, and environment management and training experience. Additionally, he has 20 years experience in the construction and mining industry.

BREAKAWAY SESSIONS

DISCUSSION POINTS

Introduction

At the end of each day, the participants split into breakaway sessions to share ideas and discuss the technologies and strategies introduced in the presentation sessions. These breakaway sessions helped develop the direction of the DHS S&T stabilization research committees. Each breakaway group used a “Breakaway Session Matrix” to generate valuable and directed conversation on the day’s topics. In addition to asking pointed questions, the matrix is set up with suggested discussion items across the top and down the left side of the page. The intention is not to fill out a grid, but rather to cross the ideas in the top row and left column to generate ideas. The matrix and key discussion points are provided below.

DAY 1: PROBLEM DEFINITION, PHYSICALITY, AND DECISION THRESHOLDS

Breakaway Session 1A: Physicality of Collapsing Buildings

Physicality of Collapsing Buildings	Redundancy in compromised structures	Standards of vertically and laterally supporting elements	Debris behavior and effect	Modeling failed (or nearly failed) building components	Modeling failed (or nearly failed) building systems	Modeling nonstructural components	Other
Ductile and brittle failures	What important parameters are needed to accurately simulate near-collapsed buildings? What are the techniques to model falling debris? How simple should these techniques be? How important is it to model secondary collapses? How important are nonstructural components?						
Changing loading patterns and demands							
Simple analysis techniques							
Role of construction materials: concrete, steel, masonry, etc.							
Role of analysis in aiding emergency managers							
Other							

Discussion

What important parameters are needed to accurately simulate near-collapsed buildings?

- Type of collapse pattern, type of construction
  - Floor construction, major connection points, materials
  - Basement/no basement
  - Above ground/below ground
  - Configuration of remaining active elements with significant mass drives potential forces
- FEMA categorization of building types
- Measures of deformation (geometry) and capacity
- Building occupancy
  - Machinery, different compartmentation
  - Nonstructural components?
  - Hazardous materials

What are the techniques to model falling debris? How simple should these techniques be?

- There are not currently any analytic models
- Technique should determine if building is in dynamic or static mode
- As debris is removed, what are the effects on remaining structure (stored strain energy)
- Is the debris providing benefit to the stability of the structure?
  - Arching (buttressing) action of debris
  - Debris is now loading structural members in abnormal directions
- Debris may be a hindrance to operations
- The amount, weight, orientation, and location of debris
- Model debris patterns to inform what happens post-event
- Training stakeholders how to read debris accurately and to predict from existing models
- Impact loading effect

How important is it to model secondary collapses?

- Secondary collapses are the key determiner of risk
- Identify where the locations for potential for secondary collapses through prioritization
- Look at connection points (key indicators)
- Look at pre-cast concrete or masonry
- What is the composition of the building? History of building type.
- Look for mass
- Less catastrophic collapse for wood buildings
- Wood gives more warning
- Through analysis followed by testing, come up with what to look for (need for testing and creating database)
- Advance WAI modeling to accommodate secondary collapses
- Continuous vs. simple supported beams

How important are nonstructural components?

- Non-obvious incipient failures of façade elements are important
- Performance-Based Design project by DHS S&T IGD might help address nonstructural components

Based on our discussion and your experience, specify input and results needed for an analysis of a building attached by an IED?

Very simple analysis (almost visual, or near instantaneous)	Simple analysis (might require some input)
• Mass aspect • Dimensions that go with supporting elements • Consequences of progressive collapse or damage • Patterns of failure (collapse) • Monitoring movement (works when ductile) • For brittle – mitigation, establish a "hot zone" • For each building type, check list (refinement of list) • Haz 3, SOG Section 1 recon form • Both specific and generic • Visible deformation	• Correlate level of cracking • Priority list • Prioritize based on areas of safety levels • There is a recon form (SOG) • Talk about fallout • Victim potential • Secondary collapse potential • Zones of relative safety • Adapt WAI studies (hi-resolution analysis results after different IED events) • How? Expected debris pattern • Identify safe access and egress paths (E.E.R.R)

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BREAKAWAY SESSIONS

DISCUSSION POINTS

Breakaway Session 1B: Thresholds and Risk Management

<table>
<tr><th>Thresholds and Risk Management</th><th>Levels of risk: Warning, dangerous, and certain failure</th><th>Component, partial, and global failures</th><th>Risk treatment (different mitigation measures)</th><th>Immediate vs. long-term risk assessments</th><th>Need for information regarding building under consideration</th><th>Validation efforts of risk assessment tools</th><th>Other</th></tr>
<tr><td>Global vs. local failure</td><td rowspan="8" colspan="7">How can the level of risk be communicated (graphical, numerical, audible, etc.)?

On a percentage scale, what is an acceptable level of risk for warning? An acceptable level of risk for danger? An acceptable level of risk for certain failure?

How extensive should a simple risk evaluation tool be for first responders? How should such a tool be organized? Does it need to be on a PDA, iPAD, etc.? How would the results of such a tool be communicated to the users?

How extensive should a simple risk evaluation tool be for engineers/architects? How should such a tool be organized? Does it need to be on a PDA, iPAD, etc.? How would the results of such a tool be communicated to the users?</td></tr>
<tr><td>Extent of initial damage, and potential for progressive collapse</td></tr>
<tr><td>Failure states of different components</td></tr>
<tr><td>Assessments of shoring effectiveness</td></tr>
<tr><td>Seismic failure modes vs. IED failure modes</td></tr>
<tr><td>Effectiveness of graphical interface</td></tr>
<tr><td>Interaction of visual judgments and automatic sensing</td></tr>
<tr><td>Other</td></tr>
</table>

Discussion

How can the level of risk be communicated (graphical, numerical, audible, etc.)?

- Start with picture catalog for visual assessment
- High, medium, low scale (rough quantitative) better than 1-10 scale
- Have to use judgment
- Improve consistency between Structural Specialist (StS) personnel judgments

On a percentage scale, what is an acceptable level of risk for warning? An acceptable level of risk for danger? An acceptable level of risk for certain failure?

- Level of risk depends on material, failure mode – some materials are inherently higher-risk
- This needs to be coordinated with monitoring/sensing community

How extensive should a simple risk evaluation tool be for <u>first responders</u>? How should such a tool be organized? Does it need to be on a PDA, iPAD, etc.? How would the results of such a tool be communicated to the users?

- It is important to note that every building is different
- Should include building type, material, event/hazard type
- Evidence-based tool for future events for quick assessment?
- Simplify BIM for decision making
- Fire department has information on at-risk buildings on computer – can modify questions to include IED
- Reach-back, Skype would provide more expertise

How extensive should a simple risk evaluation tool be for <u>engineers/architects</u>? How should such a tool be organized? Does it need to be on a PDA, iPAD, etc.? How would the results of such a tool be communicated to the users?

- BIM
- Develop for engineers who are not part of FEMA/USACE US&R
- These engineers should be on retainer/contract with the State so that there is an immediate response from a local engineer using the same tools as FEMA/USACE

BREAKAWAY SESSIONS

DISCUSSION POINTS

Based on our discussion and your experience, describe important parameters that should be included in a simple risk assessment tool for an IED-attacked building.

Field tool for immediate first responders	Tools for engineers/architects/ decision makers
1. Rugged card/FOG for quick access 2. Reach-back capability with experts 3. Rapid inspection checklist (with visuals for comparison) with building & damage information to go through the thought process before entering 4. Case studies for background knowledge 5. Training on tool is important, use State EMA as vehicle (awareness level as part of collapse curriculum)	1. Web tool, more detailed background information 2. Augment ATC 20 tool/training 3. Easy way to collect data and compare to other events 4. Shoring and advanced materials database for different situations 5. Database of progressive collapse analysis models for varying situations (columns removed in different parts of building) in combination with engineer 6. Having qualified engineer is the most valuable 7. Webinars

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DAY 2: EMERGING TECHNOLOGIES AND TESTING NEEDS

Breakaway Session 2A: Emerging Technologies

Emerging Technologies	BIM technology and interrelation with near-collapse buildings	Attributes of high performance buildings	Use of advanced materials in buildings construction	Use of advanced materials in shoring collapsing buildings	Different shoring systems	Advanced structural assessment tools and technologies	Other
Interaction of shoring systems and collapsing buildings							
Use of conventional vs. advanced materials in shoring							
Shoring of moment-resisting frames							
Shoring of buildings with shear walls or braced systems							
Shoring of brittle systems, e.g., non-reinforced masonry							
Other							

What important parameters need to be included in a BIM database to aid decision-makers and first responders?

What are the most promising shoring technologies (materials and systems)? What are the attributes of such shoring materials and systems?

How would shoring systems/materials vary with the type of building systems (moment-resisting frames, flat slabs, shear walls, steel bracings, non-reinforced masonry, etc.)?

Discussion

What important parameters need to be included in a BIM database to aid decision-makers and first responders?

- Material type, framing system
- Window glazing (blast vs. standard), any special equipment
- Retrofit systems (not necessarily just for blast)
- Access stairs
- Fire protection system
- Auxiliary power system
- Whether design includes progressive collapse or blast provisions
- Egress routes
- Special uses in buildings (oxygen tanks)
- Mechanical systems
- Hazardous materials
- Overall building configuration (column grid, floor to floor heights)
- Primary gathering areas (lobbies)

What are the most promising shoring technologies (materials and systems)? What are the attributes of such shoring materials and systems?

- Spray-on high tension/fast-setting coating, self-orienting
- FRP on wood (shoring system only?) – wood most common material
- Air bags (inside)
- Composite materials (availability and cost)
- Fasteners, pre-fabricated connectors
- Special tool to nail more nails at a time
- Plastic cribbing
- Assembly?
- Lightweight/adjustable
- Rapid deployment
- Overload warning systems
- Simple to install (fire-fighter simple)
- Availability and cost of material
- Strength
- Lateral vs. vertical shoring?
- Carbon ropes (stiffer)
- Self-healing materials (general stabilization)
- Strengthen connections (general stabilization)
- Polymer concrete
- Careful of heat generated polymer
- Health issues associated with advanced materials
- Manual/check lists for available technologies and systems

How would shoring systems/materials vary with the type of building systems (moment-resisting frames, flat slabs, shear walls, steel bracings, non-reinforced masonry, etc.)?

- Combination of system and type of damage trying to mitigate (no "one fits all" solution)
- Different for base material (steel vs. reinforced concrete)
- Study the situation, construction material and design system based on that
- Pre-stress, post-tension systems, possibility that solutions may extend far beyond the apparent location of damage

Based on our discussion and your experience, what are the most important technologies that can help first responders immediately after the event and 24 hours after the event?

Immediately	24 Hours After
• **Technologies that help locate hot zones and victims** • Smart card – read on the way to the event – include building information • Robots • Tools and processes for assessing the damage • Database of different failure and damage scenarios • Database of resources: what materials and tools to use and where to get them • Appropriate tools • Handling of cache • Battery life of tools	• **Some technology to know where victims/rescuers are at all times** • **Determine how badly the concrete is cracked or damaged** • **Ability to determine secondary collapse potential through scanning** • Tools and processes for assessing the damage • Pre-action plan/familiarization of the building using smart card technology • Robots (wireless? – need to improve tech to access in heavy concrete) • Multi-function materials that work as sensor and repair • Ultra high strength concrete • Scanning technology • Personal chips • Acoustic scanning • BIM – to get plans about building • Older buildings might not have plans and as-built condition

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BREAKAWAY SESSIONS

DISCUSSION POINTS

Breakaway Session 2B: Testing Needs

Testing Needs	Failure modes of shoring systems and materials	Destructive vs. non-destructive tests	Methods of simulating loading effects	Scaled vs. full-scale tests	Interaction of structure and mitigation measures (shoring)	Testing effects of debris	Cost of tests	Other
National Labs								
Research Organizations								
Federal/Military								
Vendors/Private								
Universities								
Other								

What are some different tests that need to be performed on different shoring systems?

What are some different tests that need to be performed on shoring materials?

How important is it to test a near-collapse component and the shoring mitigation measure? Is it adequate to simulate the near-collapse component by a simple loading mechanism?

What scaled tests are applicable for validating shoring (mitigation) methods for failing structures (or components)?

Discussion

What are some different tests that need to be performed on different shoring systems?

- Portability, weight
- Lateral loading on vertical shore simulating aftershock
- Rakers on angled walls
- Anchoring/bracing raker system
- Impact testing
- Database of test results from all organizations

What are some different tests that need to be performed on shoring materials?

- Cutting through wrap materials; use regular tools but there are OSHA issues
- Disposal
- How to identify knots/flaws/fusing cues in wood if covered. See-through materials? Other warning signs?
- Portability, weight

How important is it to test a near-collapse component and the shoring mitigation measure? Is it adequate to simulate the near-collapse component by a simple loading mechanism?

- Need loading in all 3 directions
- Shake table simulation (gussets)
- Tests need to be load controlled rather than displacement-based
- Add sensors to testing that is already in place

What scaled tests are applicable for validating shoring (mitigation) methods for failing structures (or components)?

- Shoring tests are relatively low-cost once apparatus is set up, so scaling is not necessary
- User audience relates better to full scale
- Difficult to scale down wood material because of unique properties
- Where can we test?
    - USACE Engineer Research and Development Center (ERDC)
    - Accessible to firefighters for training incorporated with testing
    - Establish rating standard for different systems?

BREAKAWAY SESSIONS

DISCUSSION POINTS

Based on our discussion and your experience, what are the most important tests that need to be considered, both for shoring systems and shoring materials?

Shoring Systems	Shoring Materials
• Testing should be load controlled • Raker testing, especially anchoring • Lateral load, angled floor/ceiling more realistic • Secondary blast on shoring • Connections	• First need to set aside time and resources to investigate state-of-the-art products/systems to test

Name	Organization
R.B. Alley	*College Station TX Fire Department*
Ahmed Al-Ostaz	*University of Mississippi, Civil Engineering*
Clint Arnett	*TEEX US&R*
Thomas Attard	*The University of Tennessee*
Michael Barker	*University of Wyoming*
Marlon Bazan	*Protection Engineering Consultants*
Brian Beadnell	*Formerly CA-TF3 and Menlo Park Fire*
J.D. Bolich	*TEEX US&R*
Gerry Brown	*Catalyst Partners*
Vince Chiarito	*U.S. Army Corps of Engineers*
Ri-Chee Chou	*Exponent, Inc.*
Kevin Claber	*UK Home Office*
Tom Coleman	*DHS Transportation Security Laboratory*
Fernando Cortez-Lira	*Analytical Research, LLC*
Jim DuPont	*Illinois Mutual Aid System US&R*
Mohammed Ettouney	*Weidlinger Associates*
Chris Gallagher	*NYPD ESU (retired)*
Mark Geraghty	*Fibrwarp Construction, Inc.*
David Hammond	*US&R CA-TF3*
Gwen Hall	*URS Corporation*
Robert Hall	*Engineering Innovations, LLC*
Matt Haupt	*URS Corporation*
Bil Hawkins	*US&R CO-TF1*
Peter Keating	*Texas A&M University*
Mila Kennett	*DHS/S&T/IGD*
Eric Letvin	*URS Corporation*
K.C. Mahboub	*University of Kentucky*
Shalva Marjanishvili	*Hinman Consulting Engineers*
David Mascarenas	*Los Alamos National Lab*
Steven McEvoy	*First Responder*

LIST OF ATTENDEES

Name	Organization
Bob McKee	*TEEX*
Will McMahon	*U.S. Army Corps of Engineers – ERDC*
Chris Mullen	*University of Mississippi*
Robin Murphy	*Texas A&M University*
Scott Nacheman	*Thornton Tomasetti*
Lawrence Nelson	*Protection Engineering Consultants*
John O'Connell	*Collapse Rescue Systems Inc.*
Mike Piper	*US&R Colorado*
Jon Rigolo	*Virginia Beach Fire Department*
Don Roy	*LA County Fire Department*
Lisa Scola	*PBS&J*
Laura Seitz	*URS Corporation*
Zachery Smith	*Fyfeco*
Holly Stone	*Stone Security Engineering*
Dean Tills	*Robert Silman Associates*
Eric Williamson	*University of Texas, Austin*