PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Report of the Seventh Joint Planning Meeting of NEES/E-Defense Collaborative Research on Earthquake Engineering

Held at the E-Defense, Miki, and Shin-Kobe, Japan
September 18–19, 2009

Convened by the Hyogo Earthquake Engineering Research Center (NIED)
NEES Consortium, Inc.

PEER 2010/109
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Report of the Seventh Joint Planning Meeting of NEES/E-Defense Collaborative Research on Earthquake Engineering

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Convened by the

Hyogo Earthquake Engineering Research Center, NIED
NEES Consortium, Inc.

October, 2009

Preface

Following an agreement between the Japan Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the US National Science Foundation (NSF), the First Planning Meeting for NEES/E-Defense Collaboration on Earthquake Engineering Research was held in 2004. This meeting laid the groundwork for a five-year joint research program related to improving understanding and reducing the seismic vulnerability of bridges and steel buildings. To formalize the collaboration, two Memorandums of Understanding (MOU) were executed, one between NSF and MEXT in September 2005 and one between the NEES Consortium Inc. (NEES Inc.) and the National Research Institute for Earth Science and Disaster Prevention (NIED) of Japan in July 2005. These MOUs cover collaborative activities through 2010.

A joint US-Japan planning meeting was held on January 12 and 13, 2009 in Arlington, Virginia, USA to discuss the need for and benefits of continued NEES/E-Defense collaboration. This small meeting identified a number of important topics of mutual interest to the US and Japan that would benefit from continued research collaboration and sharing of NEES and E-Defense resources. A follow-up meeting to discuss details of this future phase of collaboration was recommended.

The Seventh Planning Meeting was convened during September 17 and 18, 2009, to review the efforts and accomplishments of the past four and half years and to discuss continued and hopefully stronger collaboration for the coming years. The meeting, organized by NSF and the NEES Inc. in the U.S. and MEXT and NIED in Japan, was attended by leading researchers from both countries as well as representatives from NSF, MEXT and other government agencies. Overall, twenty-nine participants attended the meeting from Japan and thirty-two participants were from the U.S.

This report contains a summary of the meeting along with the recommendations and resolutions reached by the participants. Several appendices contain the list of participants, the meeting agenda and schedule, the materials presented during the plenary and breakout sessions, and a report that summarizes the recommendations delivered by individual breakout sessions where participants discussed in detail various scientific and engineering challenges that should be addressed during the upcoming NEES/E-Defense collaboration.

Acknowledgements

The Joint Technical Coordinating Committee for the NEES/E-Defense Collaborative Research Program in Earthquake Engineering would like to thank the meeting participants for making the meeting a success by generously sharing of their time, experience and ideas. The participants agree that the cordial and harmonious atmosphere at the meeting, and the candid and thoroughgoing discussions signal an outstanding future for NEES/E-Defense Collaboration.

The meeting was held at the Hyogo Earthquake Engineering Research Center (E-Defense) in Miki, Japan, and at the Crown Plaza Hotel, Kobe, Japan. The participants would like to express their gratitude to E-Defense for opening its facilities to them for this meeting, and allowing the participants to watch a large-scale shaking table test.

The meeting was hosted by the Hyogo Earthquake Engineering Research Center including making local arrangements. The support of E-Defense staff contributed greatly to the success of the meeting.

Many participants from the US and Japan attended the meeting using their own travel funds. Travel support for a significant number of the US participants was made possible by the Cooperative Agreement No. CMMI – 0402490, and subsequent amendments and supplements, between the US National Science Foundation and the NEES Consortium Inc. This support is greatly appreciated.

The findings, recommendations and conclusions contained in this report are the consensus views of the meeting participants, and do not necessarily reflect opinions of any one individual or the policy or views of the National Science Foundation, the National Earthquake Hazards Reduction Program, the NEES Consortium Inc. or other organization in the US, nor of the Ministry of Education, Culture, Sports, Science and Technology, National Research Institute for Earth Science and Disaster Prevention or the Hyogo Earthquake Engineering Research Center in Japan.

Contents

Summary and Resolutions of the First Joint Planning Meeting For Second Phase of NEES/E-Defense Collaborative Research on Earthquake Engineering

BACKGROUND

The U.S.-Japan Joint High Level Committee (JHLC) on Science and Technology emphasized, in the Joint Communiqué of the Ninth Meeting, that the two countries should cooperate on multiple aspects of earthquake-related research. During the first Japan-U.S. Workshop on Science and Technology for a Secure and Safe Society (held in February 2004), the Japan Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the US National Science Foundation (NSF) agreed to discuss opportunities for cooperative activities related to earthquake research, citing NEES/E-Defense collaboration as a specific example of such cooperation.

To realize the cooperation, the First Planning Meeting for NEES/E-Defense Collaboration was held in 2004, and the basic scheme for a five-year joint research was established. Two thrust areas, i.e., steel buildings and bridges, were given highest priority for the joint research. To formalize the collaboration, two Memorandums of Understanding (MOU) were executed, one between NSF and MEXT in September 2005 and between NEES Consortium Inc. (NEES Inc.) and the National Research Institute for Earth Science and Disaster Prevention (NIED) of Japan in July 2005. These MOUs cover collaborative activities through 2010. A small planning meeting was held in January 2009 to discuss the need for and benefits of a second phase of NEES/E-Defense collaboration. The participants unanimously recommended a second phase be carried out, and recommended a number of high priority research needs to be discussed in future planning meetings.

ISSUES DISCUSSED

The meeting was organized to review the efforts and accomplishments made during the past four years and to discuss in detail continuing collaboration beyond March 2010, when the First Phase NEES/E-Defense Collaborative Research is scheduled to expire. In the plenary session, the history of this collaborative research was reviewed, and a few notable projects that had been completed successfully were reported.

Based on the general agreement reached in the First Planning Meeting for the Second Phase of the NEES/E-Defense, held on January 12 and 13, 2009, at NSF in Arlington, Virginia, in the USA, the Japanese side proposed a series of specific topics for future NEES/E-Defense research. Six breakout sessions were organized to facilitate in-depth discussion on the type and organization of collaboration between the U.S. and Japan. The agenda of the meeting and the list of participants are shown in Appendices I and II. The materials presented during the plenary sessions are presented in Appendices III to V, while the breakout session detail and its summary are presented in Appendices VI and VII.

During the First Planning Meeting for Second Phase NEES/E-Defense, "Resilient City" was chosen as an overarching meta-theme. In the scope of Resilient City, scientific challenges and specific research needs as well as the benefit acquired through the NEES/E-Defense collaboration were identified during the meeting for the following six topics: Buildings, Nonstructural Elements, Transportation Systems, Lifelines including Geotechnical Issues, Computational Simulation, and Monitoring and Condition Assessment. To comply with the discussion and suggestions made during the meeting and to follow the themes described in the meeting's resolutions, E-Defense has proposed the follow six projects for the next phase NEES/E-Defense, namely:

(a) New materials and new technologies
(b) Base-isolation and vibration control
(c) Geotechnical engineering
(d) Energy facilities
(e) Computational simulation
(f) Monitoring

Project (a) deals with building structures in which new materials, new elements, and new systems are incorporated. The project is in commensurate with the needs associated with "Buildings." The project naturally includes "Nonstructural Elements". As readily understood, "Nonstructural Elements" are always the best candidate for payload tests.

Project (b) aims at next generation base-isolation and structural control. Issues related to "buildings" and "transportation systems" are in line with this project.

Project (c) deals with soil and underground lifelines/structures. The project naturally covers various aspects discussed in "Transportation Systems," "Lifelines" and "Geotechnical Engineering."

Project (d) focuses on energy facilities, which is closely associated with "Lifelines".

Projects (e) and (f) are naturally along the line of recommendations from the meeting. In fact, it was believed that each of Projects (a) to (d) should include aspects of Projects (e) and (f), and "Monitoring" and "Computational Simulation" are also suitable as payload tests.

RESOLUTIONS

Based on the presentations, discussions and deliberations, the participants of the Planning Meeting for the second phase of NEES/E-Defense Collaboration formulated and unanimously adopted the following specific resolutions:

- **NEES/E-Defense Collaboration should continue without interruption into Phase 2.**

  The participants agree that a second phase of the NEES/E-Defense Collaborative Research Program in Earthquake Engineering is needed and beneficial, because:

  1. The importance of the Resilient City meta-theme concept to both the US and Japan,
  2. The smooth and effective collaboration already established between NEES and E-Defense, and
  3. The significant opportunities to leverage the unique resources offered by NEES and E-Defense.

  It is strongly believed that NEES/E-Defense collaboration by the US and Japan provides the strongest mechanism to accelerate the pace of discovery and development in engineering needed to realize the goals of the earthquake disaster resilient city.

- Projects (a) to (f) are suitable for NEES/E-Defense Collaboration.

  Based on extensive discussions during the plenary and breakout sessions, the participants believed that the six project areas proposed by E-Defense provide an excellent and broad-based framework for pursuing high priority research of mutual interest to the US and Japan. The breakout session summaries in Appendix VII highlight the technical challenges raised by each of these problem areas and the social and engineering benefits of the research proposed.

- Theme structure concept is most preferable.

  Based on an evaluation of Phase 1 and comments from the participants, it is believed that a jointly developed theme structure for each of these project areas is beneficial to promote collaboration and encourage synergism among the various research efforts. As noted in Appendix VI, it is suggested that a regular schedule of tests be established, with tests related to Projects (a) New Materials and New Technologies and (d) Energy Facilities being conduced in Japanese FY 2010 and FY 2012, and Projects (b) Seismic Isolation and Vibration Control and (c) Geotechnical Engineering being conducted in Japanese FY 2011 and 2013. This schedule will provide a basis for joint planning of common theme structures to be tested on E-Defense, with opportunities for a variety of ancillary and payload projects.

- Respective task teams should be established as soon as possible.

  It was agreed that it is important that regular joint planning meetings be held to plan future tests, and accelerate exchange of information resulting from the joint NEES/E-Defense research. In particular, joint technical sub-committees need be established on each of the six project areas to:

  1. Identify the appropriate characteristics of the theme structures,

2. Establish research goals of the major joint test programs
3. Recommend needed ancillary and payload tests and analyses,
4. Facilitate collaboration, and
5. Share information obtained and promote dissemination of research findings and their use in education and practice.

- Funding agencies are encouraged to provided needed resources

  Given the importance of the research proposed, and the benefits of leveraging resources available in the US and Japan, appropriate funding agencies in the US and Japan are encouraged to provide adequate funding and other support needed to realize the benefits of the second phase of the NEES/E-Defense collaboration.

CLOSURE

The participants believe that the Seventh Planning Meeting of the NEES/E-Defense Collaborative Research Program on Earthquake Engineering was highly successful, and that NSF and MEXT should be congratulated for providing the earthquake engineering community with cutting-edge tools that will substantially accelerate progress towards the important goals of earthquake loss reduction. The attendees agree that the cordial and harmonious atmosphere at the meeting, and the candid and thoroughgoing discussions signal an outstanding future for NEES/E-Defense Collaboration.

The participants also appreciate and heartily thank E-Defense for its efforts in hosting this successful meeting.

APPENDICES

Appendix I – List of Participants
Appendix II – Agenda of Program
Appendix III – Plenary Session I (Introduction)
Appendix IV – Plenary Session II (Past Accomplishment)
Appendix V – Plenary Session III (Japanese Proposals)
Appendix VI – Breakout Sessions Guideline
Appendix VII – Breakout Session Summary

List of Participants

Name	Affiliation	Title
United States of America		
Scott A Ashford	Oregon State University	Professor and Department Head
Gregory G Deierlein	Stanford University	Professor
Reginald DesRoches	Georgia Institute of Technology	Professor and Associate Chair
Shirley J Dyke	Purdue University	Professor
Rudolf Eigenmann	Purdue University NEEScomm	Professor Co-PI, Member of Strategic Council Leader of IT
Ahmed Elgamal	University of California, San Diego	Professor
Emmanuel "Manos" Maragakis	University of Nevada, Reno	Dean of Engineering
Ken Elwood	University of British Columbia	Associate Professor
Wassim Michael Ghannoum	University of Texas at Austin	Assistant Professor
John Rives Hayes Jr	National Institute of Standards and Technology	Director, National Earthquake Hazard Reduction Program
Susan Coady Kemnitzer	National Science Foundation	Deputy Director, Division of Engineering Education and Centers
John W van de Lindt	Colorado State University	Associate Professor
Laura Nicole Lowes	University of Washington	Associate Professor

List of Participants

Name	Affiliation	Title
Stephen Alan Mahin	University of California, Berkeley	Director, Pacific Earthquake Engineering Research Center
Steven L McCabe	NEES Consortium	CEO
Jack P Moehle	University of California, Berkeley	Professor
Troy A. Morgan	Tokyo Institute of Technology	Assistant Professor
Gilberto Mosqueda	University at Buffalo	Assistant Professor
Naru Nakata	Johns Hopkins University	Assistant Professor
Gustavo J Parra-Montesinos	University of Michigan	Associate Professor
Joy M Pauschke	National Science Foundatinon	Program Director
Julio A Ramirez	Purdue University NEEScomm	Professor Center Director, Chair of the Strategic Council and PI
Andrei M Reinhorn	University at Buffalo	Professor
James M Ricles	Lehigh University	Professor
Charles W. Roeder	University of Washington	Professor
Keri L Ryan	Utah State University	Assistant Professor
Richard Sause	ATLSS Center, Lehigh University	Professor

List of Participants

Name	Affiliation	Title
Andreas Schellenberg	UC Berkeley	Postdoctoral Scholar
Bozidar Stojadinovic	University of California Berkeley	Professor
John Wallace	UCLA/NEESinc	Professor/President
James K Wight	University of Michigan	Professor
Solomon C. Yim	Oregon State University	Professor
Adda Athanasopoulos Zekkos	University of Michigan, Ann Arbor	Assistant Professor

List of Participants

Name	Affiliation	Title
Japan		
Kenichi Abe	E-Defense, NIED	Acting Director
Satoshi Fujita	Tokyo Denki University	Professor
Tsuyoshi Hikino	E-Defense, NIED	Researcher
Muneo Hori	Tokyo University	Professor
Yoshiki Ikeda	Kobori Research Complex, Kajima Corporation	Supervisory Research Engineer
Tatsuhiko Ine	E-Defense, NIED	Invited Research Fellow
Takahito Inoue	E-Defense, NIED	Chief of Planning Section
Toshimi Kabeyasawa	Tokyo University	Professor
Yoshiro Kai	E-Defense, NIED	Chief of Facilities Administration Section
Kouichi Kajiwara	E-Defense, NIED	Senior Resercher
Kazuhiko Kasai	Tokyo Institute of Technology	Professor
Kazuhiko Kawashima	Tokyo Institute of Technology	Professor
Susumu Kono	Kyoto University	Associate Professor
Taizo Matsumori	E-Defense, NIED	Senior Researcher
Rikio Minamiyama	MEXT, JAPAN	Director, Office for Disaster Reduction Research

List of Participants

Name	Affiliation	Title
Takuya Nagae	E-Defense, NIED	Senior Researcher
Izumi Nakamura	E-Defense, NIED	Senior Researcher
Masayoshi Nakashima	E-Defense, NIED	Director
Akira Nishitani	Waseda University	Vice President & Professor
Yoshimitsu Okada	NIED	President
Hisanobu Sakai	E-Defense, NIED	Researcher
Eiji Sato	E-Defense, NIED	Senior Researcher
Matsutaro Seki	E-Defense, NIED	Visiting Researcher
Hidemaru Shimizu	E-Defense, NIED	Researcher
Hitoshi Shiohara	University of Tokyo	Associate Professor
Kentaro Tabata	E-Defense, NIED	Senior Researcher
Yoshikazu Takahashi	DPRI, Kyoto University	Associate Professor
Kohji Tokimatsu	Tokyo Institute of Technology	Professor
Ikuo Towhata	University of Tokyo	Professor

Agenda – 7th NEES/E-Defense Planning Meetings
18-19 September 2009

Friday, September 18 (at E-Defense)

10:00 Leave Crowne Plaza Hotel for E-Defense (by limousine)
10:40 Arrive at E-Defense
Registration

Chair：Kentaro Tabata (E-Defense, NIED) & Steve McCabe (NEESinc)

11:00-11:20 Opening Session
Welcoming Remarks
Joy Pauschke (NSF)
Rikio Minamiyama (MEXT)
Jack Hayes (NEHRP)
John Wallace (NEESinc)
Yoshimitsu Okada (NIED)

11:20-12:40 Plenary Sessions (Overview R/D Plan in US & Japan)
History of NEES/E-Defense Research Collaboration
Masayoshi Nakashima (NIED)
Summary of First Planning Meeting for Second Phase of NEES/E-Defense Collaborative Research on Earthquake Engineering
John Wallace (UCLA)
Introduction of New Research Project Plan in Japan
Masayoshi Nakashima (NIED)
Future of NEES and Overview R/D Plan in US
Joy Pauschke (NSF)
Introduction of New NEES Operation
Julio Ramirez (NEESops, Purdue Univ.)

12:40-14:00 Lunch & Tour of E-Defense site
Tour Guide： Hidemaru Shimizu＆Tsuyoshi Hikino (E-Defense, NIED)

Chair：Kentaro Tabata (E-Defense, NIED) & Laura Lowes (Univ. of Washington)

14:00-14:30 Outline of full scale test of a high-rise structure
Takuya Nagae (E-Defense, NIED)
14:30-15:00 Introduction of NEES projects using E-Defense
Gregory Deierlein (Stanford)

15:00-15:30 Test observation
15:30-16:00 Break
16:00-17:00 Plenary Discussion (New Japanese research themes)
New materials and new technologies
Taizo Matsumori (E-Defense, NIED)
Base-isolation & vibration control

Eiji Sato (E-Defense, NIED)

Geotechnical engineering

Kentaro Tabata (E-Defense, NIED)

Energy facilities

Izumi Nakamura (E-Defense, NIED)

Numerical simulation

Tatsuhiko Ine (E-Defense, NIED)

IT (Data repository)

Hisanobu Sakai (E-Defense, NIED)

17:15 Leave E-Defense (by limousine)

19:00-21:00 Banquet at Crowne Plaza Hotel

Moderator：Yoshiro Kai (E-Defense, NIED) & Julio Ramirez (Purdue Univ.)

Saturday, September 19 (at Crowne Plaza Hotel)

Chair：Kouich Kajiwara (E-Defense, NIED) & Reginald Des Roche (Georgia Tech)

9:30-10:45 Plenary Session

9:30-10:45 Overview of accomplished projects

Kazuhiko Kawashima (Tokyo Institute of Technology)

Kazuhiko Kasai (Tokyo Institute of Technology)

10:45-11:00 Break

11:00-12:15 Breakout session1*

(New materials and new technologies, Base-isolation & vibration control, Geotechnical engineering)

12:15-13:00 Lunch

13:00-14:00 Breakout session1*(cont.)

14:00-15:00 Breakout session2*

(Energy facilities, Numerical simulation, Monitoring)

15:00-15:15 Cof fee Break

15:15-15:45 Breakout session2*(cont.)

15:45-16:00 Break

Chair：Masayoshi Nakashima（NIED）, Stephen Mahin（UC Berkeley）

16:00-16:50 Present breakout session findings

16:50-17:00 Closing Session

17:00 Adjo urn meeting

*: See “separate sheet” for detail including tentative assignment.

NEES/E-Defense Collaboration
– A Historical Note –

by

Masayoshi Nakashima
E-Defense
National Research Center for
Earth Science and Disaster Prevention (NIED)

A Partial History of US-Japan on EE for Past Thirty Years

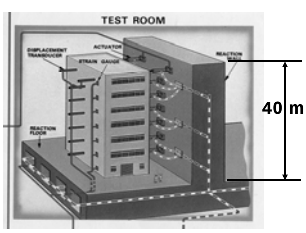
US-Japan joint Program Utilizing Large Scale Testing Facilities (1975 – 2000)
(Sponsors: NSF and Japanese Ministry of Construction)

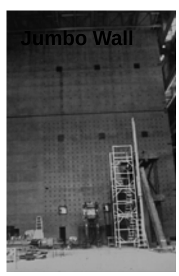
RC buildings (Phase I), steel buildings (Phase II), masonry buildings (Phase III), pre-cast buildings (Phase IV), composite structures (Phase V), and smart structures (Phase VI).

US-Japan Joint Project on Urban Disaster Mitigation (1997 – 2002)
(Sponsors: NSF and Ministry of Education)

NEES/E-Defense Project (2005 – 2009)
(Sponsors: NSF and MEXT)

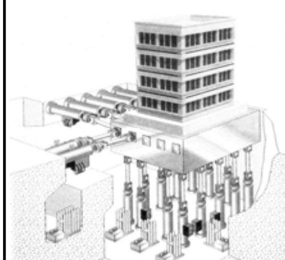
US-Japan joint Program Utilizing Large Scale Testing Facilities (1975 – 2000)





Jumbo Testing Facilities at Building Research Institute (built in 1980)

NEES/E-Defense Collaboration



E-Defense
Ready in April, 2005

NEES
Ready in October, 2004

NEES/E-Defense Collaboration Memorandum of Understanding (MOU)

MEXT & NSF (National Science Foundation) :
Research Collaboration on Disaster Mitigation

NIED & NEES (J. Brown Jr. Network for Earthquake Engineering Simulation) :
Collaboration on Joint Research Using NEES/E-Defense

NIED-NEES, August 3, 2005

MEXT-NSF, Sept 13, 2005

A History of Planning and JTCC Meeting

Planning Meetings

First	April, 6 to 8, 2004 at Kobe
Second	July 12 to 13, 2004 at Washington DC
Third	January 17, 2005 at E-Defense
Fourth	August 2 to 3, 2005 at E-Defense
Fifth	September 27 to 29, 2006 at E-Defense
Sixth	September 28 to 30, 2007 at E-Defense

(First for Second Phase of NEES/E-Defense
January 12 to 13, 2009 at Washington DC

JTCC Meetings

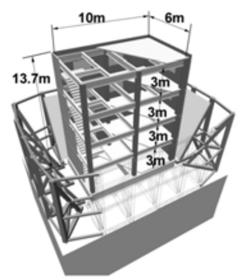
First	August 8, 2005 at E-Defense
Second	April 17, 2006 at San Francisco
Third	June 24, 2009 at Honolulu

Planning Meetings

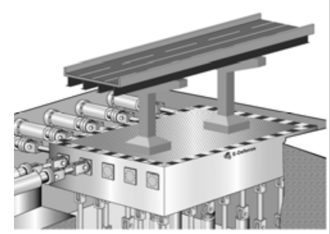
JTCC Meetings

Prof. Katayama and Dr. Hayama of NIED

NEES/E-Defense Collaboration Selected Targets

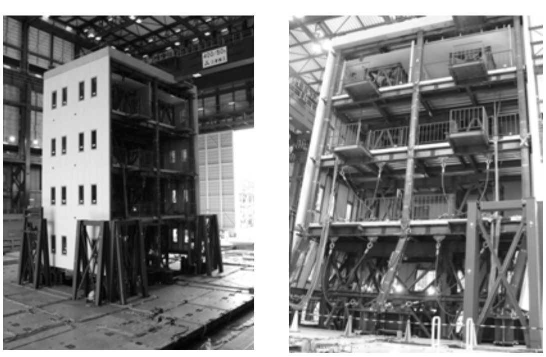


Steel



Bridges

Complete Collapse Test of Four-Story Steel Moment Frame

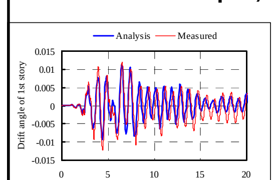


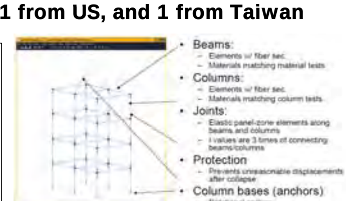
E-Defense Steel Collapse

Blind Prediction Contest for Steel Collapse Test

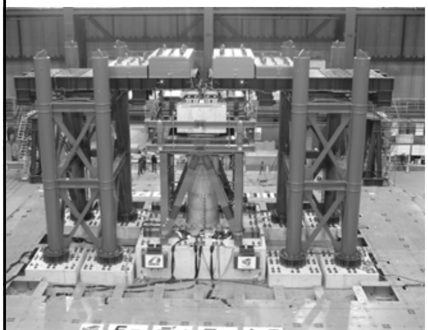
Categories: Researchers (30) and Practitioners (17)
Categories: 2D analysis and 3D analysis
14 teams from Japan; 10 teams from the US; 7 teams from Taiwan, etc.
Target Response – 60% Takatori

Winners: 3 from Japan, 1 from US, and 1 from Taiwan





Bridge Component Test



Specimen
Diameter = 1.8 m
Height = 7.5 m
Total Height
= 12 m

C1: old practice, shear
C1: closer view

NEES Projects in Liaison with E-Defense

NEESWood: Development of a Performance-Based Seismic Design Philosophy for Mid-Rise Woodframe Construction
PI: John van de Lindt

Controlled Rocking of Steel-Framed Buildings with Replaceable Energy Dissipating Fuses
PI: Gregory Deierlein

International Hybrid Simulation of Tomorrow's Braced Frame Systems
PI: Charles Roeder

TIPS - Tools to Facilitate Widespread Use of Isolation and Protective Systems
PI: Keri Ryan

Simulation of the Seismic Performance of Nonstructural Systems
PI: Emmanuel Maragakis

NEESWood: Development of a Performance-Based Seismic Design Philosophy for Mid-Rise Woodframe Construction

www.engr.colostate.edu/NEESWood

A NEESR Small Group Project; Funded at $1.37M over four years.
National Science Foundation Grant No. CMMI-0529903 (NEES Research) and CMMI-0402490 (NEES Operations).

Project Team
John W. van de Lindt
Rachel A. Davidson
Andre Filiatrault
David V. Rosowsky
Michael D. Symans

Technical Collaborators for E-Defense Tests

The objective of the NEESWood project is to develop a new performance-based seismic design philosophy for mid-rise woodframe construction, enabling such construction to be an economically viable option in seismic regions within the U.S. and around the world.

- Participants include 5 universities, NIED-Japan, >20 industry partners, a community college, an advisory committee, and undergraduate, graduate, and post-graduate students.
- Testing at SUNY Buffalo NEES site completed in 2006
- Testing in Year 4 at NIED-Japan's E-Defense shake table facility in Miki City, Hyogo, Japan to confirm design method for six-story condominium
- Project outcomes will:
  - Safely increase the height of woodframe construction to six stories in seismic regions.
  - Make residential structures less susceptible to earthquake damage.

George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)

NEESWood: Development of a Performance-Based Seismic Design Philosophy for Mid-Rise Woodframe Construction

www.engr.colostate.edu/NEESWood

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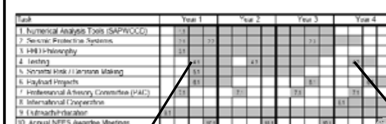
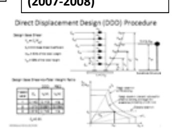


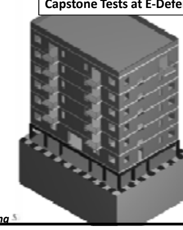
- Full-scale, 17000 sq ft living space
- 4 retail shops at level 1
- 13 families of four (13 two-bedroom units)
- 10 couples or single occupants (10 one-bedroom units)
- 18, 20-ton containers shipped from West Coast to Japan

Validate methodology with Capstone Tests at E-Defense (2009)

Benchmark Tests University at Buffalo (2006)

Develop new design approach using results (2007-2008)

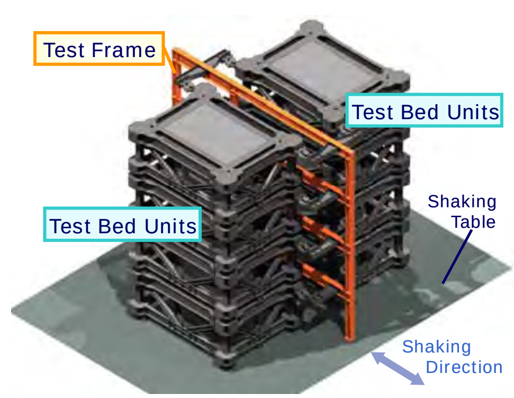




George E. Brown, Jr. Network for Earthquake Engineering

NEESWood: Final Verification Test At E-Defense In July 2009

Versatile "TestBed" at E-Defense



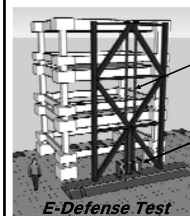
NEESR-SG: Controlled Rocking of Steel-Framed Buildings with Replaceable Energy Dissipating Fuses

- Gregory Deierlein, Sarah Billington, Helmut Krawinkler and Xiang Ma, *Stanford University*
- Jerome Hajjar and Matt Eatherton, *University of Illinois*
- Mitsumasa Midorikawa, *Hokkaido University*
- Toru Takeuchi, *Tokyo Institute of Technology*
- Tsuyoshi Hikino, *NIED E-Defense*
- David Mar, *Tipping & Mar Assoc. and* Gregory Luth, *GPLA*

E-Defense

NEES George E. Brown, Jr. Network for Earthquake Engineering Simulation

Innovative Rocking Frame System



Active post-tensioning

Energy Dissipating Fuse

- Large-Scale Validation
  - fuse/rocking frame interaction
  - PT, fuses, and rocking details
- Proof-of-Concept
  - constructability
  - design criteria
- Performance Assessment
  - nonlinear computer simulation
  - life-cycle benefit cost analysis

Develop a new structural building system that employs *self-centering rocking* action and *replaceable** fuses to provide safe and cost effective earthquake resistance.

Key Concept – design for repair

Control Rocking: Final Verification Test At E-Defense In August 2009

Types of Test Facilities Desired

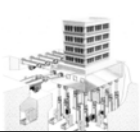
- ❐ Where most of the equipment should be housed or whether a large distributed network was more desirable.
- ❐ Whether the main investment should be in one large shake table or in a series of smaller pieces of equipment.

Synergy

Complementarity

A combination of "central location" and "one large facility (shaking table)"	A combination of "a large distributed network" and "a series of (relatively) smaller pieces of equipment,"

Synergetic and Complementary Efforts



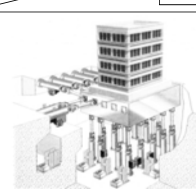
Synergy

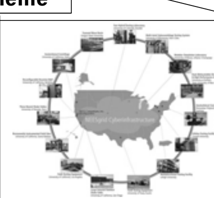
Complementarity

A combination of "central location" and "one large facility (shaking table)"	A combination of "a large distributed network" and "a series of (relatively) smaller pieces of equipment,"
A tool for ultimate verication	A revolution of EE research environment – Concepts of laboratory sharing, remote participation, and data sharing

Toward Genuine Complementary Efforts Under a Common Umbrella

Meta Theme





Test on large-scale theme structures for final verification	A variety of tests using various unique facilities for examinations into basic mechanisms and accumulation of fundamental knowledge

Summary

First Planning Meeting
Phase 2 NEES/E-Defense Collaborative
Earthquake Engineering Research Program

Held at NSF, Arlington, VA, USA, January 12-13, 2009

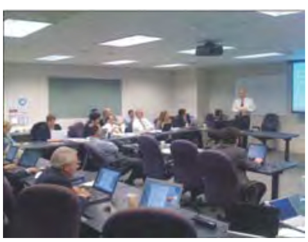
NEES E-Defense NIED

Second Planning Meeting, E-Defense, Miki & Kobe, Japan September 18-19, 2009

First Planning Meeting

- ✓ Discuss desirability of a second five-year phase of NEES/E-Defense Collaborative Research Program on Earthquake Engineering
- ✓ Identify high priority research topics of mutual interest to the US and Japan that:
  - → Utilize the unique capabilities of the E-Defense and NEES facilities
  - → Lead to major new discoveries, solve important scientific challenges and result in innovative and transformational approaches to earthquake loss reduction.
  - → Provide opportunities for solid collaboration and synergy
- → Identify future actions needed to accomplish desired outcomes

Meeting held at NSF



Participants:
- 9 from Japan
- 25 from US

Representing:
- Government agencies
- Researchers with diverse interests
- NEES & E-Defense

Agenda

Monday, Jan. 12
- Introductory Material
- Vision for Next Phase - Global Issues
  - White Papers and Plenary Discussion
    - → Why are large scale tests still needed?
    - → Organizational framework for next phase
- Vision for Next Phase - Meta-Themes
  - White Papers and Plenary Discussion
    - → Earthquake Disaster Resiliency
    - → Preparing for the Big One
    - → Low probability, high consequence events
- Lunch
  - Breakout Sessions on Meta-Themes
    - → Earthquake Disaster Resiliency
    - → Preparing for the Big One
    - → Low probability, high consequence events
  - Plenary session
    - → Summarize and discuss findings of breakout sessions
- Dinner (6:30 pm)

Short White Papers and discussions on:
Global Issues
Meta-themes

Agenda

Tuesday, January 13, 2009
- Specific Engineering Challenges - Part 1
  - White Papers and Plenary Discussion
    - → Buildings including Foundations
    - → Nonstructural Elements and Socio-economic Issues
    - → Bridges and Transportation Systems including Foundations
  - Breakout Sessions on Specific Engineering challenges - 1
  - Plenary session (Summarize and discuss findings of breakout sessions)
- Lunch
- Specific Engineering Challenges - Part 2
  - White Papers and Plenary Discussion
    - → Lifelines (including underground structures)
    - → Numerical simulation
    - → Health monitoring, damage assessment, new technologies
  - Breakout Sessions on Specific Engineering challenges - 2
  - Plenary session (Summarize and discuss findings of breakout sessions)
- Plenary Session on Recommendations and Resolutions
  - Specific recommendations
  - Recommendation for follow-up meeting
- Adjourn

Engineering Challenges
Engineering Challenges
Recommendations

Proceedings

Contains:
- White papers
- Breakout session reports
- Workshop resolutions
- Participant list
- Agenda

Observations

Contemporary urban society in US and Japan:

- Are recognized to be more vulnerable to earthquakes due to complex interaction and interdependency of engineered structures and systems
- Have higher expectations for safety and continuity of normal social, cultural and business operations

- US & Japanese research communities each working to address these issues
- NEES and E-Defense provide uniquely complementary tools to address engineering and science challenges.
- Second Phase of NEES/E-Defense Collaboration on Earthquake Engineering best means to resolve problems of mutual interest.

Resolutions

By concentrating on different aspects of a common meta-theme, rapid progress possible

Enabling the Earthquake Resilient City

- Provides a strong framework for addressing all of the high priority topics identified
- Provides life safety, while minimizing damage and speeding recovery
- Many new and exciting engineering and scientific challenges addressed

Need research on:

- Building systems
- Lifelines
- Transportation Systems
- Underground structures

Includes:

- Numerical and experimental simulation
- Health monitoring and prognosis
- New protective systems and advanced technologies, high performance and sustainable materials
- Protecting contents and nonstructural components

Resolutions

Strong collaboration is desired among projects and disciplines to achieve overall goal of meta-theme

Recommended that:

- "Theme Structures" be devised to focus efforts by different groups
- Joint Japan-US "capstone" experiments be considered

Implementation actions

- Joint Technical Coordinating Committee needed
  - Form Technical Subcommittees on each major theme area
- Additional planning meetings needed to refine scope of joint research

Mechanism established for coordinating US side of program

NSF has funded four-year coordination effort

- Publicizing opportunities, activities and outcomes in conjunction with NEEScomm and NSF
- Encouraging broad participation by various means, including:
  - Funding travel to meetings by investigators having a diversity of interests, gender, ethnicity and age, engineering practitioners, specialized experts, and students.
- Annual NEES/E-Defense planning and coordination meetings in Japan
- Periodic Technical Subcommittee Meetings in the US
- Technical support for managing theme structures
- Facilitate communications

PI: Stephen Mahin

NEES/E-Defense Collaboration Research Plan (from 2010) in E-Defense

by

Masayoshi Nakashima
E-Defense
National Research Center for
Earth Science and Disaster Prevention (NIED)

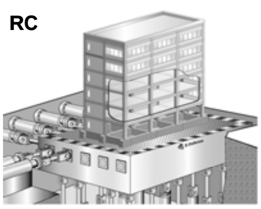
Past, Present, and Future of E-Defense Large-Scale Shaking Table Test

Year	02	03	04	05	06	07	08	09	10	11	12	13	14
Special Project (MEXT)													
RC Buildings													
Wood Houses													
Soil and Geotech													
Steel High-Rises													
Base-Isolated Hospitals													
Earthquake Engineering Project (NIED)													
Steel Buildings													
RC Bridges													
Numerical Shaking Table													
Data Repository													
New Materials and Technologies									●		●		
Base-Isolation and Structural Control										●		●	
Lifelines and Geotech										●		●	
Energy Facilities									●		●		

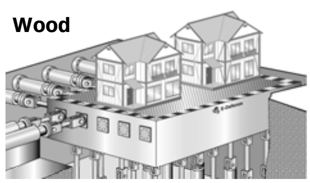
● : Large Shaking Table Test Planned

Special Project (MEXT) from 2002 to 2006

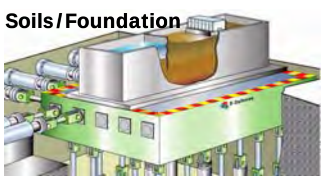
RC



Wood



Soils/Foundation



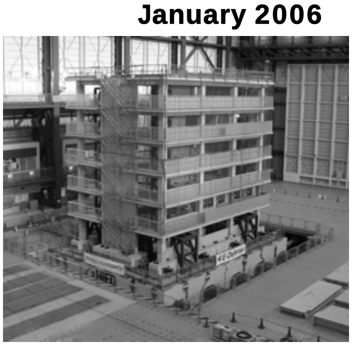
Wood Houses: Effectiveness of Retrofit

November 2005

Test click here

RC Buildings: Existing Performance in Early 1970s Design/Construction

January 2006



Test click here

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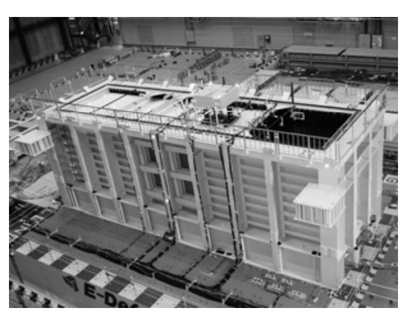
Liquefaction and Lateral Spreading

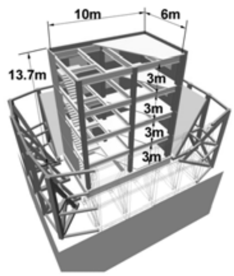
March 2006



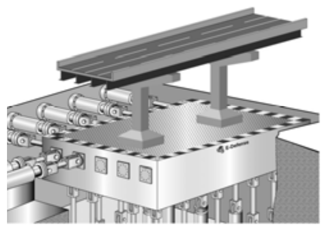
Box global click

Box local click

NEES/E-Defense Collaboration (from 2005 to 2009)



Steel

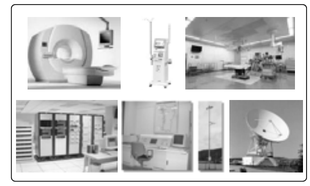

Bridges

Special Project (MEXT) from 2007 to 2011

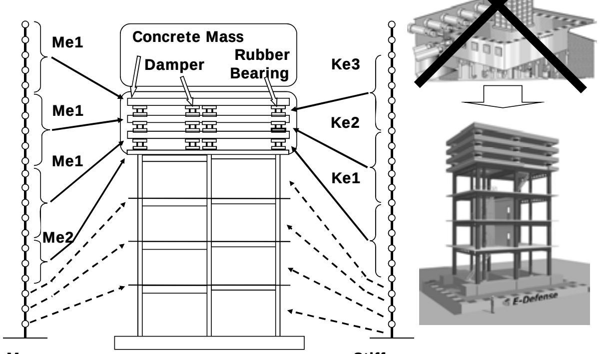
Evaluation and Assurance of Safety and Functionality of Urban Infrastructure

Response of High-Rise Steel Building Subjected to Long-Period, Long-Duration Ground Motion

Assessment of Functionality in Medical Facilities



Substructure Model for High-Rise Steel Building



Construction of Specimen


Rubber Bearings


Specimen

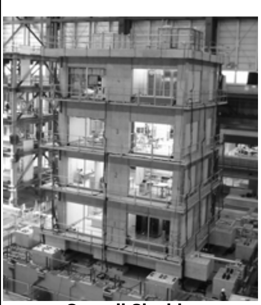

Steel Damper


Piping

High-Rise

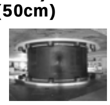

Partition Wall

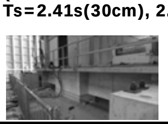
Four Story RC Hospital Base-Isolation Systems


Overall Sloshing

JMA Sannomaru


Type I: Natural Rubbers and Steel Dampers (Clearance: 500 mm)
Ts=2.56s (30cm), 2.70s (50cm)


Type II: High Damping Rubbers (Clearance: 300 mm)
Ts=2.41s(30cm), 2.52s(50cm)


Fixed Base

Resolutions Adopted in First Joint Planning Meeting for Second Phase of NEES/E-Defense Collaborative Research Washington DC, USA January 11 to 12, 2009

Resilient City as a Common Meta-Theme

The three meta-themes discussed in the meeting, i.e., "Disaster Resilient Communities", "Preparing for the Big One", and "Low-Probability, High-Consequence Events" are linked in many ways. The fundamentals of the first meta-theme are the damage reduction and quick recovery. These require developments of new materials and technologies that would enhance the performance of various components that form the urban area. Methods to detect the damage quickly and systems that can be repaired (or re-built) with minimal interruption of life and business are also the important topics to consider. In the second meta-theme, developments of new materials and technologies are the key to the prevention of a downward spiral of deterioration. The third meta-theme has much in common with the preceding two in light of the specific scientific challenges to be pursued. Thus, it was agreed that the 'Resilient City' provided a mutually important goal upon which members of the US and Japanese earthquake engineering communities could work and that US-Japan collaboration would accelerate realization of this goal and leverage the resources available in both countries.

Resolutions Adopted in First Joint Planning Meeting for Second Phase of NEES/E-Defense Collaborative Research

Scientific Challenges and Specific Research Needs

Buildings

The Resilient City, with undertones of low damage, quick recovery, and sensible rebuilding, needs new building materials, technologies and systems that efficiently control damage, as well as smart structures that can “tell you where it hurts.” These high performance structures perform well whatever (within reason) is thrown at them, and sustain damage that can be quickly found and repaired. Attention should be focused on methods to improve the resilience of existing structures. Several concepts provide particularly attractive avenues to pursue through NEES/E-Defense collaborative research: Structures with clearly defined and replaceable fuses; self-centering systems (unbonded post-tensioned cast-in-place walls, seismic isolation (including use in high-rise structures), rocking/uplifting systems (including structure-foundation-soil interaction effects), new and innovative structural systems, etc.); Structures with improved nonstructural systems, including unibody systems that utilize nonstructural components as part of the lateral load resisting system; new high performance materials that are less susceptible to damage; super-resilient structures. Large-scale NEES and E-Defense tests of complete structural systems are important to provide essential “proof of concept” demonstrations as well as the quantitative data needed to calibrate design and analysis methods.

Resolutions Adopted in First Joint Planning Meeting for Second Phase of NEES/E-Defense Collaborative Research

Scientific Challenges and Specific Research Needs

Nonstructural Elements

Nonstructural Elements. – Damage to nonstructural components and contents contribute significantly to the safety of engineered structures during and following earthquakes and the cost and duration needed for repairs. Many nonstructural components are complex, often extending throughout a structure and interacting with other nonstructural systems (electricity, communications, etc.). The behavior of these systems is not adequately understood, and plentiful opportunities exist to develop improved nonstructural components that are more resistant to damage, or structural systems that substantially reduce damage to nonstructural components and systems. E-Defense and NEES tests provide many opportunities to improve our understanding of and ability to control the factors that govern the seismic performance of nonstructural elements and systems.

Resolutions Adopted in First Joint Planning Meeting for Second Phase of NEES/E-Defense Collaborative Research

Scientific Challenges and Specific Research Needs

Transportation Systems

Transportation systems are vital to the health, prosperity, and security of modern society. Recent earthquakes have shown these systems can be vulnerable to earthquake damage with unacceptable socio-economic consequences. Damage-free bridges with minimal loss of functionality and repair time should be explored, with cost effectiveness in mind, to facilitate post-earthquake emergency response and the rapid recovery of the effected region. Specific research needs include the development of damage-free smart bridges using innovative materials, devices, and configurations, the development of bridge configurations that enable faster repair, and the development of damage-free foundations subjected to large ground movement.

Resolutions Adopted in First Joint Planning Meeting for Second Phase of NEES/E-Defense Collaborative Research

Scientific Challenges and Specific Research Needs

Lifelines, including geotechnical issues

The focus of the research should be on buried lifelines and other underground structures. Damage to such buried structures during large earthquakes has serious implications for the life of a city as it may interrupt essential transportation, power and water supply functions, as well as trigger destructive fires following the earthquake. There are large and complex underground structures whose seismic performance and interaction with surrounding soils are not yet well understood. Engineering and scientific challenges are mainly in the areas of soil-structure interaction (SSI) and geotechnical research. Specific research needs where E-Defense/NEES Collaboration would be most helpful were identified as follows: (i) response of subway stations, tunnels, and buried pipes; (ii) strategies to improve performance of underground structures; (iii) prevent flotation of underwater tunnels; (iv) development and evaluation of ground improvement and remediation strategies; (v) permanent ground deformation hazard and its effects, especially in challenging and heterogeneous soil profiles; and (vi) soil-structure interaction studies of both underground and above ground structures considering the whole structure-foundation-soil system. Tests at E-Defense should be generally planned as part of research programs including appropriate centrifuge and smaller shake table tests as well as a computational effort.

Resolutions Adopted in First Joint Planning Meeting for Second Phase of NEES/E-Defense Collaborative Research

Scientific Challenges and Specific Research Needs

Computational Simulation

Numerical simulation of the full range of behavior of 3D structure-foundation-soil systems up through collapse is a basic tool needed to evaluate the seismic resistance and safety for a resilient city. Specific research areas include improvement of models of materials and components, particularly for non-ductile and deteriorating modes of behavior, development of algorithms and software systems that conform to modern computer architectures, simulation of collapse of 3D structural systems, and representation of the uncertainty in behavior. A true integration between experimentation and simulation modeling is needed to realize robust, high fidelity numerical simulation capabilities Hybrid tests and large scale shaking table tests are essential to carry out coordinated structure-foundation-soil interaction tests at a range of scales to improve the current simulation models and algorithms that use massively parallel computation.

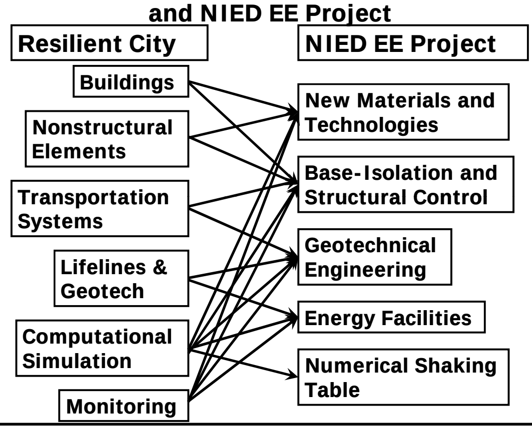
Resolutions Adopted in First Joint Planning Meeting for Second Phase of NEES/E-Defense Collaborative Research

Scientific Challenges and Specific Research Needs

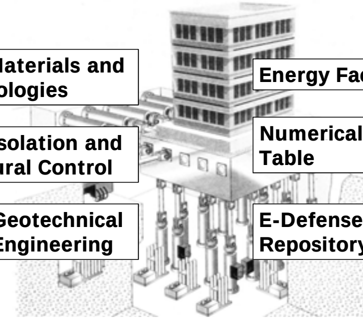
Monitoring and condition assessment

Structural health monitoring systems can provide vital information on the state of structure (a) before an earthquake leading to repair and strengthening, (b) during the emergency response period providing information on critically damaged or collapsed structures, and (c) during the recovery period information on the type and degree of damage of large number of structures reducing the recovery time. NEES and E-Defense tests provide important opportunities for conducting parallel structural health monitoring and prognosis projects that develop and implement structural health monitoring systems, and validate and calibrate damage diagnosis and prognosis algorithms. All these activities are needed to increase the resiliency of the earthquake-affected region.

Interaction Between "Resilient City" Approach and NIED EE Project



Introduction of NIED EE Project
From 4:00 PM to 5:30 PM on September 18



Project (a) : New Materials and New Technologies

Objectives — *Keywords : R/C structure, New construction, Resilient city*

Verify seismic performance of new reinforced concrete structures using E-Defense shaking table.

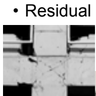
Research Topic

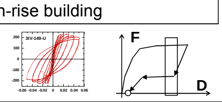
Current standard v.s. New materials, new technology

- Damage process of beam hinges
- Failure of various types of walls
- Ultimate capacities of columns
- Failure of beam-column joints
- Residual deformations

- High-strength concrete and steel
- High-performance walls
- Self-centering systems
- Improved nonstructural components

A) Medium-rise or low-rise building
B) High-rise building



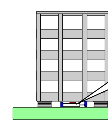


Project (b): Base-isolation & Vibration Control

OUTLINE

Propose next generation seismic isolation and vibration control systems that cope with long period and short period earthquake motions. The new proposing technology will be proven by E-Defense, aiming at being applied to important urban facilities.

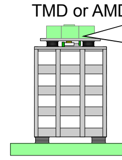
(2) Active or Semi-Active seismic isolation against long period earthquakes



Actuator or controllable damper

•Reduction of excessive relative displacement
•Motion Free in Absolute Space

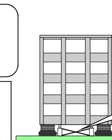
(1) Hybrid seismic isolation with TMD or AMD



Combination of seismic isolation system and TMD or AMD

•Control of resonance phenomena
•Motion Free in Absolute Space

(3) 3D seismic isolation



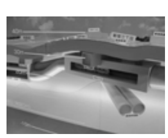
Next generation 3D seismic isolation including vertical isolator

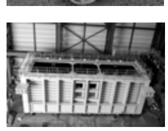
Response reduction against vertical motion

Project (c) : Geotechnical Engineering

- Evaluation of seismic performance of lifeline structures -

- To maintain demanded performance of lifelines after a large earthquake, investigate their behavior and develop performance-evaluation methods
  - Targets = transportation systems in an urban area (subway, railroad, expressway...)
- Perform E-Defense tests of a large-scale model on underground lifeline structures
  - Assume a subway station or expressway tunnel
  - Investigate behaviors (response, permanent deformation, SSI, floatation...) of the model with complex conditions such as shield/cut-and-cover tunnels, curves, complicated sections, traversing heterogeneous layers
    - ← *Advantage of a "large-scale" model*
  - Compare various tests and computational simulations with "benchmark" E-Defense results
    - ← *Case histories of "artificial disasters"*
    - Evaluate influence of scales and others to propose a testing guideline for design such as PBD





Project (d) : Energy Facilities

Objective

To clarify the seismic safety margins and structural integrity of components of energy facilities under large seismic motions, especially over the design level.

* Energy facilities :
Electrical generating facilities, High-pressure gas facilities, …
* Components of energy facilities :
Piping systems, Supports, Containers, Tanks, …

Piping systems will be tested at first.

Image of the shake table experiment

✓ Shake table test - to clarify the seismic response and failure modes of components
✓ Non destructive inspection during the test - to detect the invisible damage before failure
✓ Numerical Analysis - to establish the numerical model to estimate the failure mode of the components

Project (e) : Computational Simulation

Achievements of E-Simulator : Virtual Shaking Table

・ADVENTURE Cluster: Adjusting Platform of E-Simulator (Commercial finite element package specially tuned for Parallel Computation)

(a) FE Collapse Analysis of 31 Story Super High-rise Steel Building Frame

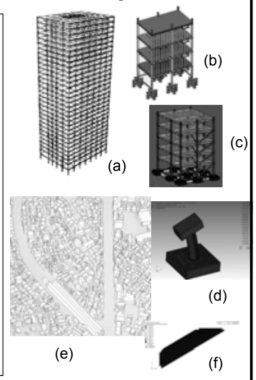
(b) FE Analysis of Collapse Experiment on 4-story Steel Moment Frame

(c) FE Analysis of the Experiment on Passively-Controlled 5-story Steel Building with Dampers (Input Model Data)

(d) PDS-FE Analysis of the Experiment on RC Bridge Pier

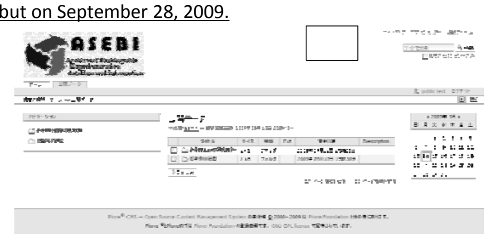
(e) Integrated Earthquake Simulation of Urban Regions

(f) FE Dynamic Collapse Analysis of Steel Building Components (Conventional Technique Improvements)



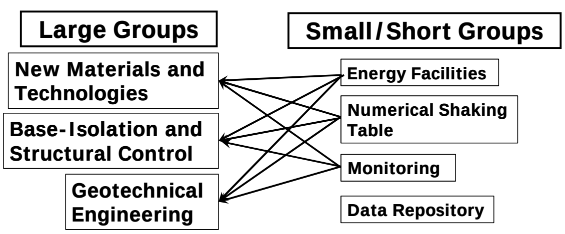
E-Defense Data Archives

- Nickname: ASEBI (Archives of Shaking table Experimentation dataBase and Information)
- Built on the ZOPE/Plone (Contents Management System) to reduce operation cost.
- It is currently available only for users in Japan.
- Debut on September 28, 2009.



NEES / E-Defense Meeting

Discussions in Breakout Sessions From 11:00 AM to 4:00 PM on September 19



Suggested issues to discuss:

1) Comments and suggestions to Japanese projects from US
2) Research plans in US and comments from Japan
3) Possible issues for collaboration
4) Complementary research strategies

George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)
FY 2000-FY 2004: Major Research Equipment and Facilities Construction (MREFC)
FY 2005-FY 2014: Operations, Research, Education, Outreach, and Training

Update: George E. Brown, Jr. Network for Earthquake Engineering Simulation Operations FY 2010-FY 2014

Presented at
7th NEES/E-Defense (Phase 2) Planning Meeting
Miki City and Kobe, Japan
September 18, 2009

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Division of Civil, Mechanical and Manufacturing Innovation
National Science Foundation
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National Science Foundation

National Science Board (NSB)
Director
Deputy Director
Office of the Inspector General (OIG)
Office of Cyberinfrastructure
Office of Equal Employment Opportunity Programs
Office of the General Counsel
Office of Integrative Activities
Office of International Science & Engineering
Office of Legislative & Public Affairs
Office of Polar Programs

NEHRP Activities

Biological Sciences (BIO)
Computer & Information Science & Engineering (CISE)
Engineering (ENG) NEES
Geosciences (GEO)
Mathematical & Physical Sciences (MPS)
Social, Behavioral & Economic Sciences (SBE)
Education & Human Resources (EHR)
Budget, Finance & Award Management (BFA)
Information & Resource Management (IRM)

NEES for the Engineering Community: 2010-2014

NEES Timeline

1989 and 1994	Loma Prieta, CA and Northridge, CA earthquakes
1994 October	NEHRP Reauthorization (PL 103-374) requires earthquake engineering research experimental capabilities assessment
1995-1998	EERI workshop report (1995) on "Assessment of Earthquake Engineering Research and Testing Capabilities in the United States" and several additional workshops
1998 November	NSB approves NEES for NSF FY 2000 budget (NSB-98-187)
2000-2004	MRE/MREFC period (15 facilities, cyberinfrastructure, and consortium)
2004 September	Construction completed
2004 May	NSB authorizes operations award (NSB-04-92) to NEES Consortium, Inc. (NEESinc) (five-year cooperative agreement)
2004 October	NEES operations and research commence
2004-present	Annual research program solicitations; NEES/E-Defense partnership
2008 June	NSF 08-574, NEES Operations FY 2010-FY 2014, solicitation issued
2009 October 1	NSF Cooperative Agreement to Purdue University for NEES Operations: FY 2010-FY 2014 http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0927178
2010 - 2012	NEES Assessment/study
> FY 2014	NEES beyond 2014 informed by NEES Assessment/study

NEES Program at NSF

National Science Foundation
Directorate for Engineering
Division of Civil, Mechanical and Manufacturing Innovation

Program Partnerships

NEES Operations (NEES Ops)
Program Coordination
NEES Research (NEESR)

Coordinating Headquarters Purdue University
Research Awards (Annual Solicitation)
Project Partnerships
Facility Partnerships

14 Experimental Facilities
Cyberinfrastructure
Education, Outreach, & Training

Resources for Research Topics, but not limited to:

Visit NEHRP.gov web site
"Research Needs Reports"
http://www.nehrp.gov/library/researchneeds.htm

NEES Research Directions

- *Strategic Plan, National Earthquake Hazards Reduction Program FY 2009-2013*
  http://www.nehrp.gov/pdf/strategic_plan_2008.pdf
- *Grand Challenges for Disaster Reduction: Priority Interagency Earthquake Implementation Actions,* A Report of the Subcommittee on Disaster Reduction, National Science and Technology Council,
  http://www.sdr.gov/185820_Earthquake_FINAL.pdf
- *Preventing Earthquake Disasters: The Grand Challenge in Earthquake Engineering. A Research Agenda for the Network for Earthquake Engineering Simulation (NEES),* a 2003 report from a panel organized by the National Research Council of the National Academies to develop a long-term agenda for earthquake engineering research requiring NEES experimental resources
  http://www.nap.edu/catalog.php?record_id=10799
- *Prioritized Research for Reducing the Seismic Hazards of Existing Buildings* (Applied Technology Council, ATC-73, 2007)
  http://www.nehrp.gov/pdf/atc73.pdf
- *Research Required to Support Full Implementation of Performance-Based Seismic Design* (NIST GCR-09-917-2, 2009)
  http://www.nehrp.gov/pdf/NISTGCR09-917-2.pdf

NEES Research Directions – Upcoming Workshops

- *Vision 2020: An Open Space Technology Workshop on the Future of Earthquake Engineering, St. Louis, Missouri, January 2010*
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0957648
- *Coordinating Workshops for the NEES/E-Defense Collaborative Research Program in Earthquake Engineering (Phase 2)*
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0958774
- *Tsunami Research Colloquium, October 19-20, 2009, Chapel Hill, NC, sponsored by DHS S&T*
  https://www.dhs.gov/files/events/scitech.shtm#tsunami
- *Workshop on NEES for Geotech, Coastal, etc. Engineering Research…November 9-10, 2009 at NSF (planned)*

NEHRP NEESR Award Success Stories

Seismic Waves

http://www.nehrp.gov/plans/index.htm#success

NEES/E-Defense: Performance-Based Seismic Design Philosophy for Mid-Rise Woodframe Construction (NSF Award CMMI-0529903)

Two-story, wood frame town house test on NEES shake tables at University at Buffalo

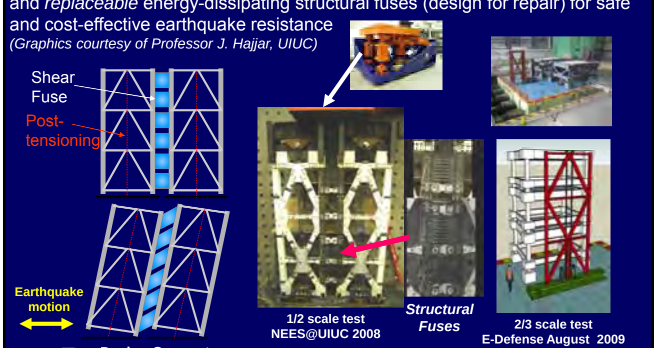
Six-story, wood frame building test on E-Defense shake table in Japan

Reference: http://www.engr.colostate.edu/NEESWood/index.shtml

NEES/E-Defense: Next Generation Earthquake-Resistant Systems (NSF Award CMMI-0530756)

New structural steel-frame building system using *self-centering rocking* action and *replaceable* energy-dissipating structural fuses (design for repair) for safe and cost-effective earthquake resistance

(Graphics courtesy of Professor J. Hajjar, UIUC)



Japan's Port and Airport Research Institute (PARI) Tsunami and Geotechnical Engineering Research

- Visit on September 17, 2009 by Professor Solomon Yim (Oregon State) and Joy Pauschke (NSF)
- Photos courtesy of PARI

Timeline for NEES Post-FY 2014 Assessment

Date By (approx)	Activity
2010 Feb	Award made for NEES assessment study • Accomplishments of NEES research and operations and future potential • Viability of NEES to remain state of the art beyond FY 2014 • Needed equipment and cyberinfrastructure upgrades • Earthquake engineering experimental capabilities worldwide/availability
2011 Dec	Assessment report completed and submitted to NSF
2012	Decision by NSF senior management about NEES post-FY 2014
2012 Oct	Communications to community, solicitation issued (TBD)?

Upcoming NSF Funding Opportunities

- Interdisciplinary Research (IDR) (NSF ENG)
  http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503439&org=ENG&from=home
- Partnerships for International Research and Education (PIRE)
  http://www.nsf.gov/pubs/2009/nsf09505/nsf09505.htm
- NEES Research (NEESR)
  http://www.nsf.gov/pubs/2009/nsf09524/nsf09524.htm

Network for Earthquake Engineering Simulation (NEES)

NEEScomm Team

Julio Ramirez
Center Director, Chair of the Strategic Council, and PI

September 2009

NEEScomm

Purdue University
University of Florida
University of Kansas
University of Michigan
San Jose State University
University of Texas-Austin
University of Washington
Fermi National Laboratory

Network for Earthquake Engineering Simulation

NEEScomm's EOT Involves…

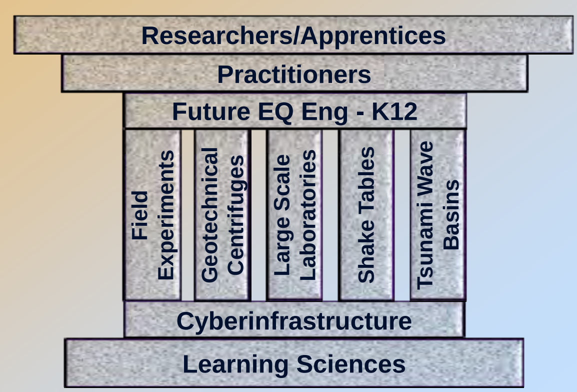
- **E**ducation of research talent of *undergraduate and graduate students*
- **O**utreach to *practitioners, K12 learners and the general public*
- **T**raining of all *professionals* involved in the process of generating quality experiments at the sites.

Network for Earthquake Engineering Simulation

PURDUE UNIVERSITY
Discovery Park

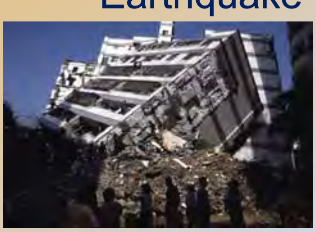
Network for Earthquake Engineering Simulation

NEES Academy



Network for Earthquake Engineering Simulation

Earthquake Risk



Dali City

1999 Taiwan Earthquake

NEEScomm Vision:

Transform NEES into a global, cyber-enabled organization for earthquake and tsunami research and education

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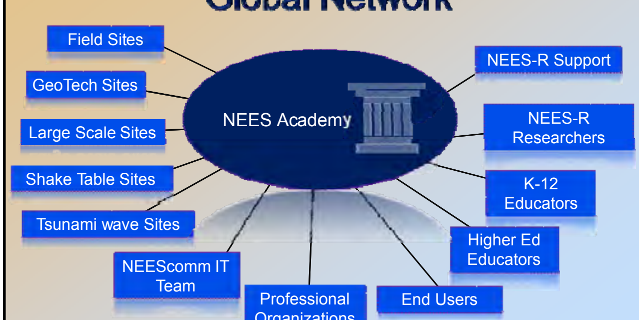
Network for Earthquake Engineering Simulation

Connecting Sites into a Global Network



Network for Earthquake Engineering Simulation (NEES)

NEEScomm IT Vision

Rudi Eigenmann
Co-PI, Leader of IT, Member of Strategic Council

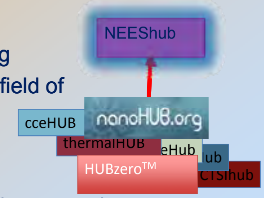
September 2009

Purdue University
University of Florida
University of Kansas
University of Michigan
San Jose State University
University of Texas-Austin
University of Washington
Fermi National Laboratory

Network for Earthquake Engineering Simulation

IT Background: HUBzero^{tm} A Leading Cyberinfrastructure

- Best known through nanoHub.org
- Serving 90,000 in highly diverse field of nanotechnology
- Proven community building
- Underlying platform HUBzero^{tm}
- 8 hubs exist, 2 in construction, 10 proposed

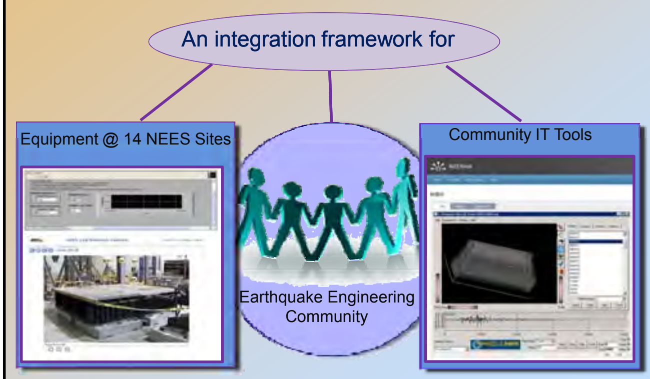


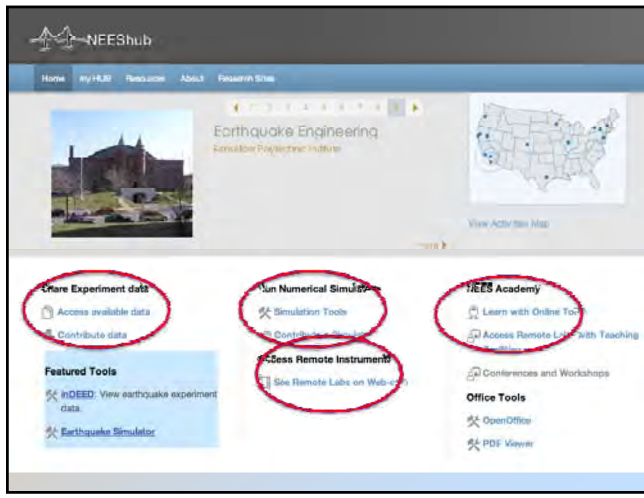
We are creating a NEEShub

10

Network for Earthquake Engineering Simulation

Production-Quality Cyberinfrastructure





Network for Earthquake Engineering Simulation

Challenges Creating the NEES Cyberinfrastructure

- Data, data, data….
  - Capturing, curating and presenting project data so that others can understand NEES experiments.
  - Example of a project data view
- Diversity of NEES sites
  - 14 sites with 6 classes of equipment
- Requirement gathering and analysis
  - From sites, researchers, community, HQ

Network for Earthquake Engineering Simulation

What is New About this Technology?

Direct execution of software tools on the Web

- eliminates download and installation of tools, such as data viewers and numerical simulators
- eliminate long data transfer times; data and tools are co-located

12

NEESR-SG: Controlled Rocking of Steel-Framed Buildings with Replaceable Energy Dissipating Fuses

Gregory G. Deierlein, Sarah Billington, Helmut Krawinkler, Xiang Ma, Alejandro Pena, Eric Borchers, *Stanford University*

Jerome F. Hajjar, Matthew Eatherton, Noel Vivar, Kerry Hall, *University of Illinois*

Toru Takeuchi, Kazuhiko Kasai, Shoichi Kishiki, Ryota Matsui, Masaru Oobayashi, Yosuke Yamamoto, *Tokyo Institute of Technology*

Mitsumasa Midorikawa, Tetsuhiro Asari, Ryohei Yamazaki, *Hokkaido University*

Tsuyoshi Hikino, *Hyogo Earthquake Engineering Research Center, NIED*

David Mar, *Tipping & Mar Associates* and **Greg Luth**, *GPLA*

E-Defense

JISF

NEES

George E. Brown, Jr. Network for Earthquake Engineering Simulation

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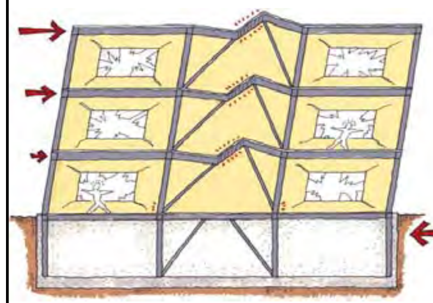
Code Seismic Design
Protect Life Safety



Throw-away technology: Structure and Architecture absorbs energy through damage

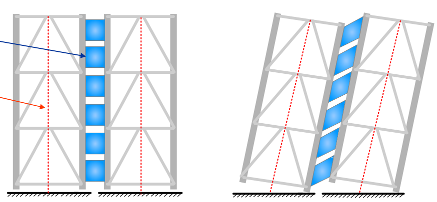
Large Inter-story Drifts: Result in architectural & structural damage

High Accelerations: Result in content damage & loss of function

Deformed Section – Eccentric Braced Frame

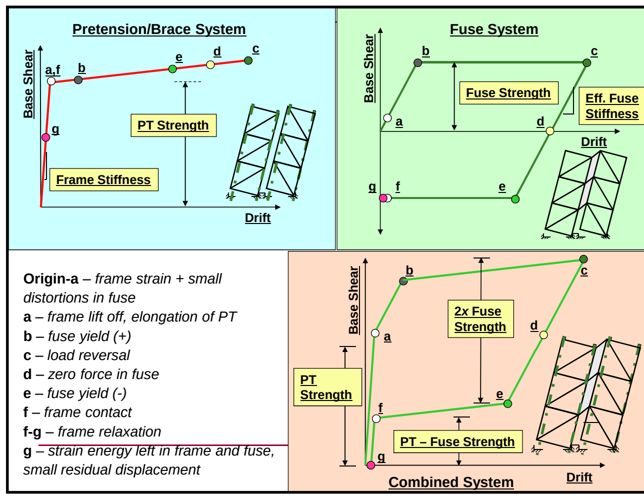
TIPPING · MAR + associates structural engineers

New Rocking Frame System

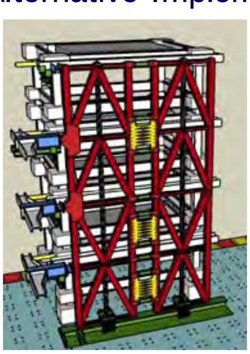


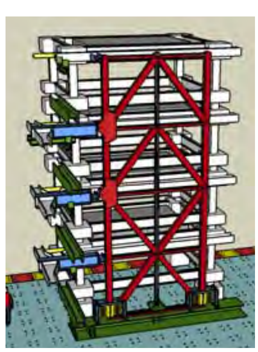
Develop a new structural building system that employs *self-centering rocking* action and *replaceable** fuses to provide safe and cost effective earthquake resistance.

**Key Concept – design for repair*



Alternative Implementations





Dual Frame | Single Frame

Research Scope

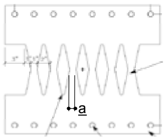
- System Design Development
  - parametric design studies
  - shear panel fuse design and testing
  - building simulation studies
- Subassembly Frame/Fuse Tests
  - quasi-static cyclic loading
  - PT rocking frame details & response
  - fuse/frame interaction
  - model calibration
- Shake Table System Tests
  - proof-of-concept
  - large scale validation

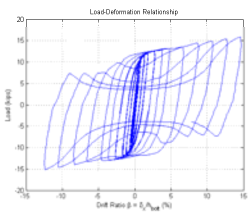
Stanford

NEES - Illinois

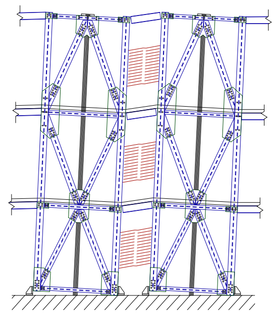
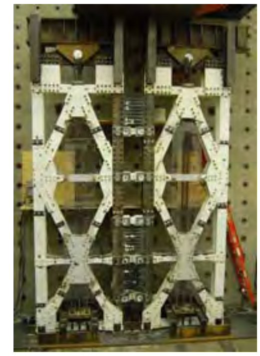
E-Defense

Energy Dissipating Steel Fuse Tests

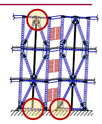
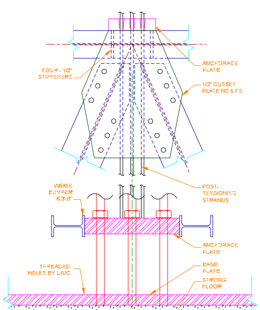


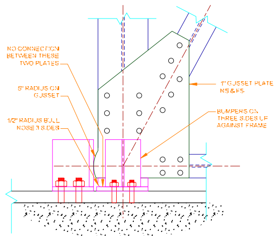
Dual Frame Test (1/2 scale) – U. Illinois

Key Details

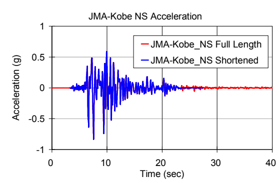



PT Anchorage

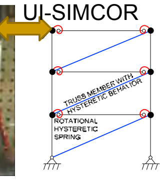


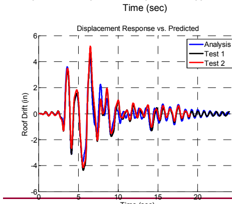
Rocking Base

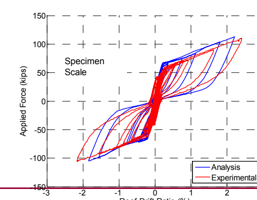
Preliminary Results: Hybrid Simulation



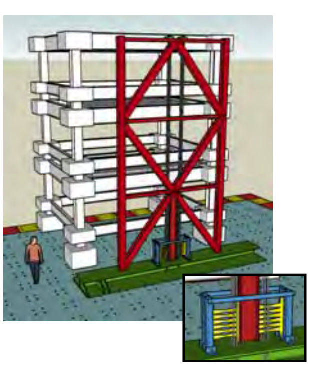
UI-SIMCOR





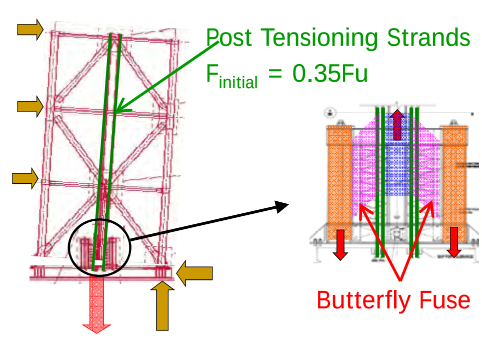


E-Defense Shake Table Test (August 2009)



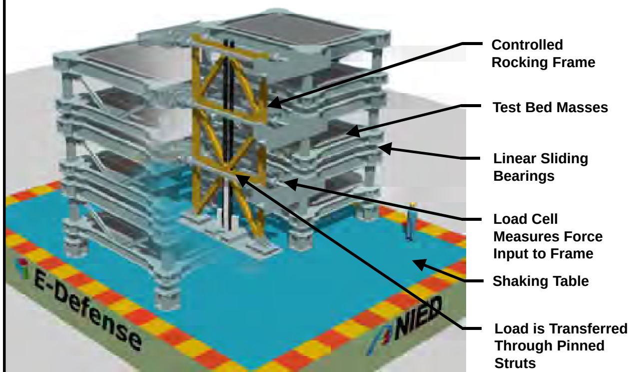
- Large-Scale Validation
  - fuse/rocking frame interaction
  - rocking base details
  - post tensioning
  - replaceable fuses
- Proof-of-Concept
  - design concept & criteria
  - constructability
- Performance Assessment
  - nonlinear computer simulation

Rocking Frame Behavior

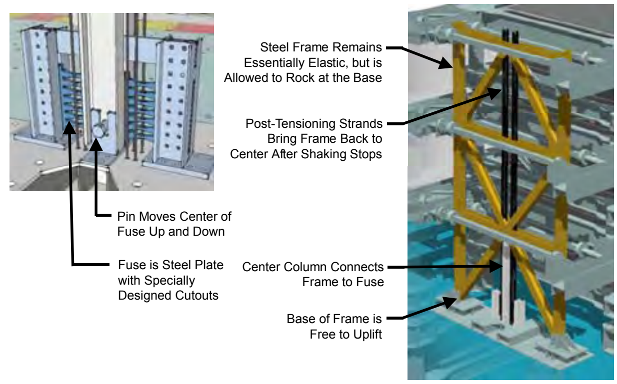


$$M_{OT,resistance} = (F_{PT} + F_{fuse})*e$$

E-DEFENSE TEST SETUP

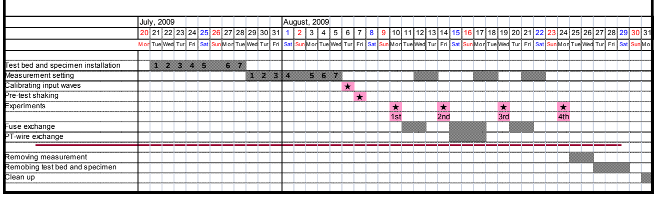


TEST A1 CONFIGURATION



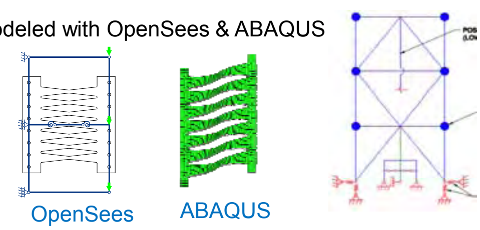
6-shaking days over 3 weeks

- Main Test Variable – Fuse Types
  - Shear Fuses and BRB Fuse
- Ground Motion – JMA and Northridge
  - 50/50, 10/50, 2/50 + higher (onset of PT fracture)
- Retensioning/Replacement of PT

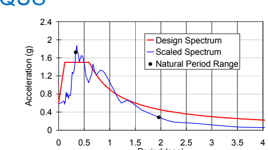


Nonlinear Time History Analysis

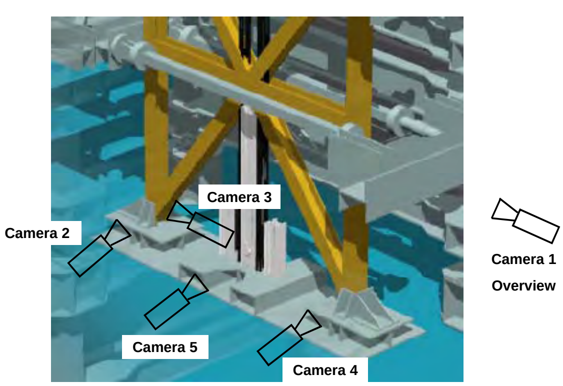
- Modeled with OpenSees & ABAQUS



- JMA Kobe Ground Motion
  - 50% in 50 yr (0.20)
  - 10% in 50 yr (0.46)
  - 2% in 50 yr (0.69)

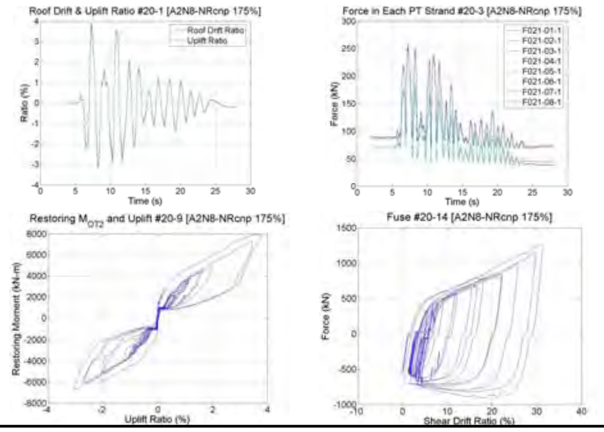


CAMERA LOCATIONS



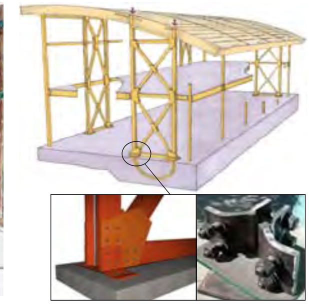
Test monitoring and data reduction

Shake Table Simulation Data



Collaboration with Industry Partners

"Early Adopters" of System Innovations

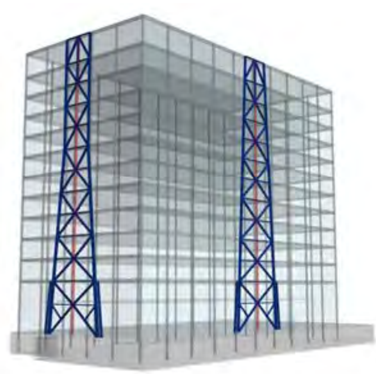


Orinda City Offices

Architect: **Siegel and Strain Architects**

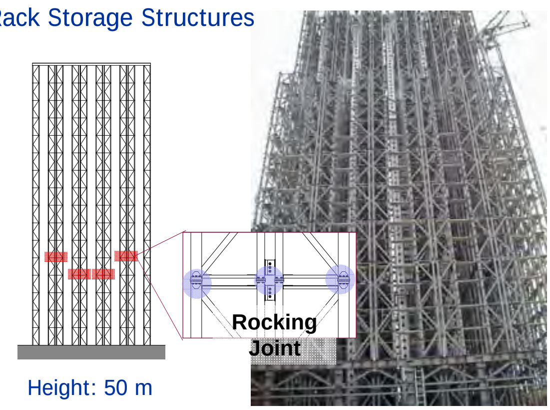
TIPPING · MAR + associates structural engineers

Concept for Single Rocking Frame Retrofit



TIPPING · MAR + associates structural engineers

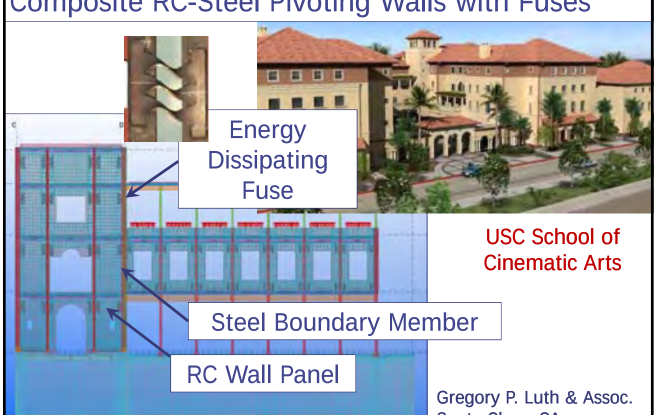
Rack Storage Structures



Height: 50 m

Prof. Akira Wada - Japan

Structural System: Composite RC-Steel Pivoting Walls with Fuses



USC School of Cinematic Arts

Gregory P. Luth & Assoc.
Santa Clara, CA

Innovation and Design Research

- **Thematic Concept**
  - life cycle design for earthquake effects
  - damage control & design for repair
- **Engineering Design Features**
  - controlled rocking & self-centering
  - energy dissipating replaceable fuses
- **Performance-Based Engineering Framework**
  - quantification of decision variables (losses, downtime)
  - integration of hazard, response, damage, loss
- **Development & Validation**
  - large scale testing and computational simulation

Elements of Success

Elements of Success

- **Innovative topic that fostered collaboration**
  - new/innovative (not encumbered by current practice)
  - evolving ideas with few pre-conceived notions
- **Shared institutional commitment**
  NSF, NIED (steel project)
- **Team committed to collaboration**
  - Stanford and UIUC
  - Tokyo Inst. of Tech., Hokkaido Univ., and Kyoto Univ.
  - NIED/E-Defense
  - Practicing engineers and industry
- **Extensive student involvement**
- **Fantastic NIED Project Manager *(MVP: T. Hikino)***

Elements of Success (cont'd)

- **Financial Support**
  - NSF and NIED
  - AISC, JISF, Nippon Steel, JSPS and others
  - Stanford and UIUC (fellowships)
- **Advance Planning**
  - Shake table dates --- set 2 years ahead of test date
  - Supporting sponsors – contacted 1 to 2 years ahead
  - Budget/Contract --- finalized 1 year ahead (almost)
  - Specimen Drawings --- finalized 6 to 12 months ahead
  - Instrumentation plan – finalized 6 months ahead
  - Data processing – 2 weeks ahead
- **Trust, patience and attention to details**

Things you might not think of …

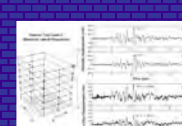
- **Exchange Rates**
  - 120Y/$ then, 90Y/$ now

- **Research Contracting**
  - Intellectual Property
  - Payment Terms ($ - Yen)
  - Laws and accounting practices
- **Long term travel/housing**
- **Workflow, communication & collaboration tools**
  - beyond e-mail, Webex, and Skype

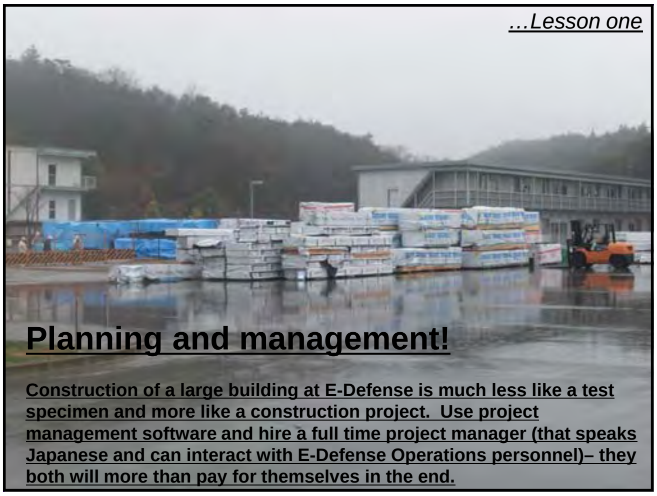
Elements of Success:
Ideas
People
Commitment

A few lessons learned during the NEESWood Capstone tests at E-Defense

Prepared by John van de Lindt
Colorado State University



NEES/E-DEFENSE Planning Meeting, Kobe, JAPAN, 18 September 2009


…Lesson one
Planning and management!
Construction of a large building at E-Defense is much less like a test specimen and more like a construction project. Use project management software and hire a full time project manager (that speaks Japanese and can interact with E-Defense Operations personnel)– they both will more than pay for themselves in the end.


…Lesson two
Financial: Leverage!
Construction of a large test specimen in Japan is difficult financially without strongly leveraging funds.
National Science Foundation


…Lesson three
General: Don't "sweat" the small stuff and communicate!
Communication at each step of the project is key. A daily meeting is important to make sure everyone knows what is happening that day.


Thank you!
Contact Information:
Professor John W. van de Lindt
jwv@engr.colostate.edu
Colorado State
This material is based upon work supported by the National Science Foundation under Grant No. CMMI-0529903 (NEES Research) and CMMI-0402490 (NEES Operations). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the investigators and do not necessarily reflect the views of the National Science Foundation.
National Science Foundation

7th NEES/E-Defense Planning meetings, 2nd Day
Crowne Plaza Hotel, Kobe, Japan, September 18, 2009

Overview of E-Defense Test Projects on Steel Buildings

Kazuhiko Kasai

Professor, Tokyo Institute of Technology
Leader, E-Defense Steel Building Research Project

The objective of this project is to clarify “actual seismic performance” of conventional and value-added steel buildings.

The most realistic tests of full-scale building specimens were conducted, using the world’s largest shaking table. Catastrophic ground motions of the 1995 Kobe Earthq. were applied.

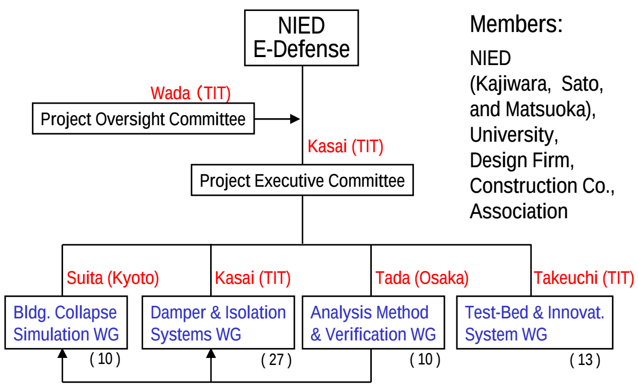


Fig. 1 Organizations of E-Defense Steel Projects

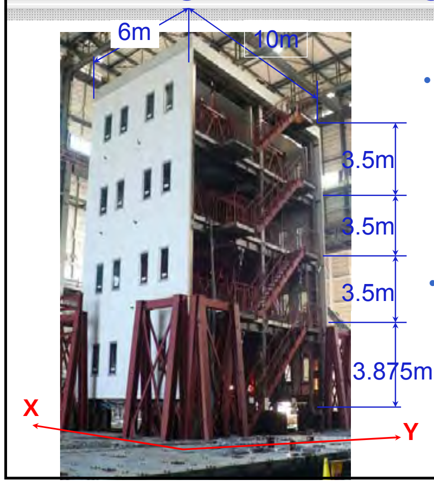
(1) Bldg. Collapse Simulation WG

For conventional moment resisting frame (MRF), find:

- Structural performance of the building under design-level ground motions.
- Safety margin against collapse to the ground motions beyond design-level.
- Functional performance of buildings limited by the behavior of non-structural components
- Actual structural behavior up to collapse useful to calibrate and advance analytical simulations.
  → Blind analysis contest

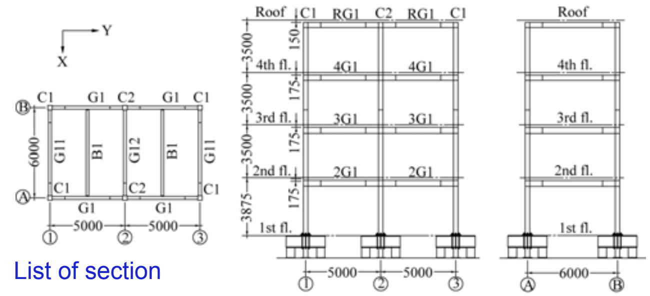
The test produced 945 channels of data.

Design of Building Specimen
5



- 4-story, 2-bay by 1bay
  - 10m in Y direction
  - 6m in X direction
  - 3.5m story height
  - 14m overall height
- Total weight 2,055 kN
  - Natural Period
    1st mode 0.901s
    2nd mode 0.293s

Steel Materials and Members
6

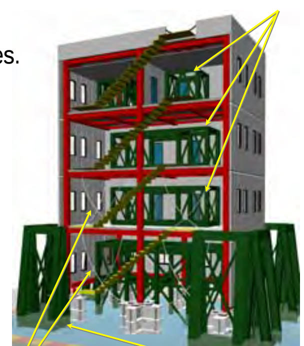


List of section

	Beam			Column	
Floor	G1	G11	G12	Story	C1,C2
Roof	H-346x174x6x9	H-346x174x6x9	H-346x174x6x9	4th	RHS-300x300x9
4th	H-350x175x7x11	H-350x175x7x11	H-340x175x9x14	3rd	RHS-300x300x9
3rd	H-396x199x7x11	H-400x200x8x13	H-400x200x8x13	2nd	RHS-300x300x9
2nd	H-400x200x8x13	H-400x200x8x13	H-390x200x10x16	1st	RHS-300x300x9

Safeguard System
7

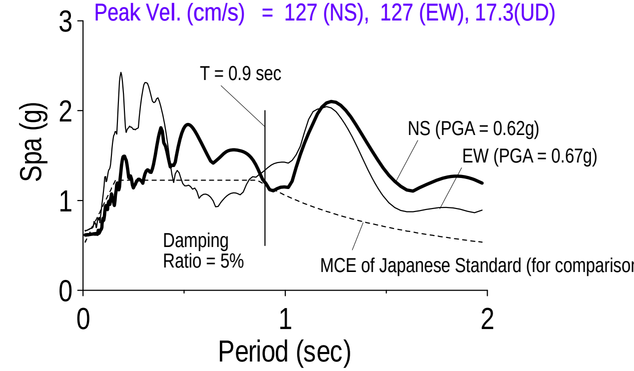
- The safeguard protects shaking table during the collapse test.
- It consists of three safety features.
  - Diagonal Wires
  - Tables on Floors
  - Surrounding Fences
- Story drift angle is held not to exceed 0.3 rad.



E-Defense Steel Research Project, First 2.5 Years

Used JR Takatori Record (x 0.2, 0.4, 0.6, 1.0)

Peak Acc. (cm/s^2) = 606 (NS), 657 (EW), 279 (UD)
Peak Vel. (cm/s) = 127 (NS), 127 (EW), 17.3(UD)

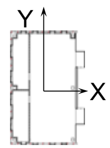


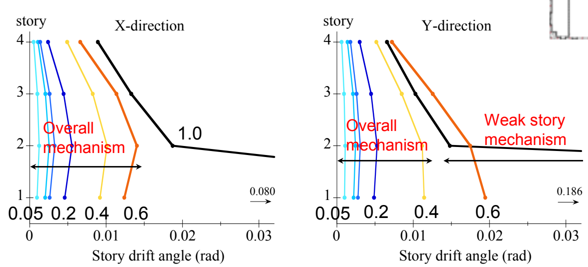
E-Defense Steel Research Project, First 2.5 Years

Shift of mechanism

9

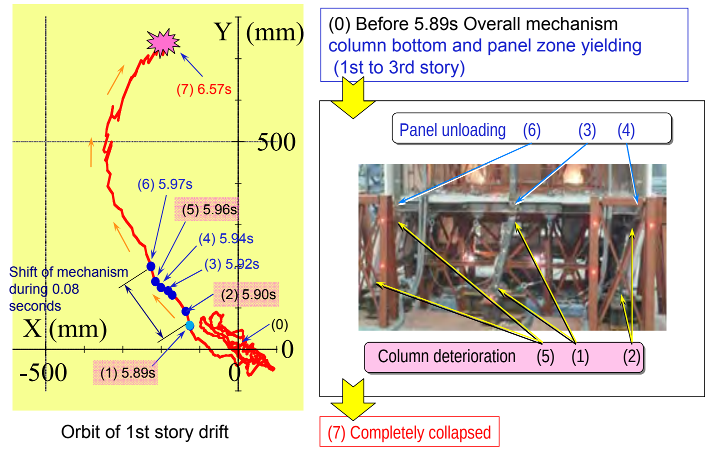
- X direction : overall mechanism until 0.6 Takatori
- Y direction : shift to weak story mechanism by 0.6 Takatori





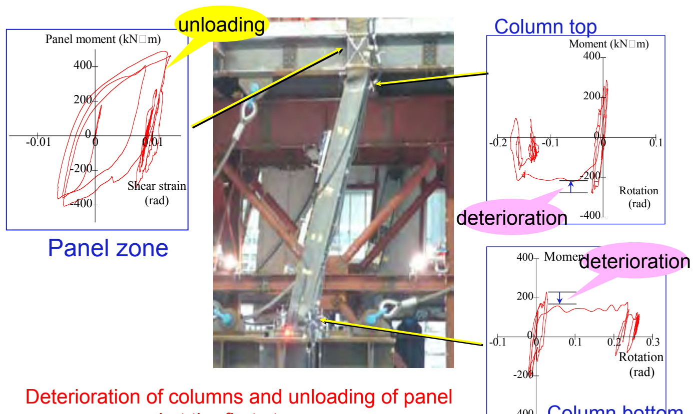
Sequence of failure by 1.0 Takatori

10

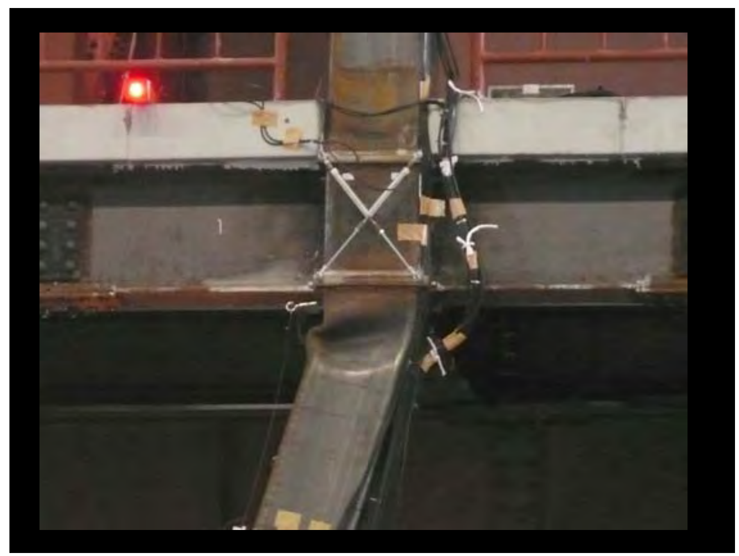


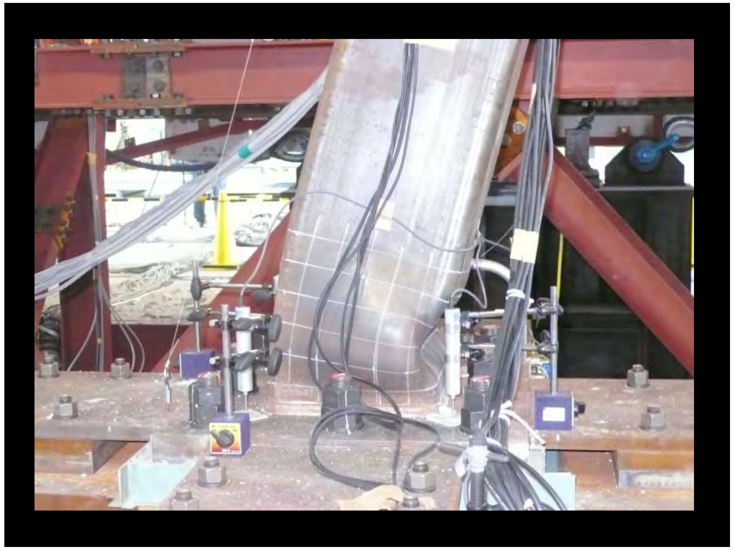
Behavior of structural members

11



Deterioration of columns and unloading of panel zones occurred at the first story.





Conclusions and Future Studies (Bldg. Collapse Simulation WG)

The steel moment frame performed well under design basis earthq. But it collapsed under catastrophic earthq., shifting from overall sway mechanism to weak story mechanism with column instability.

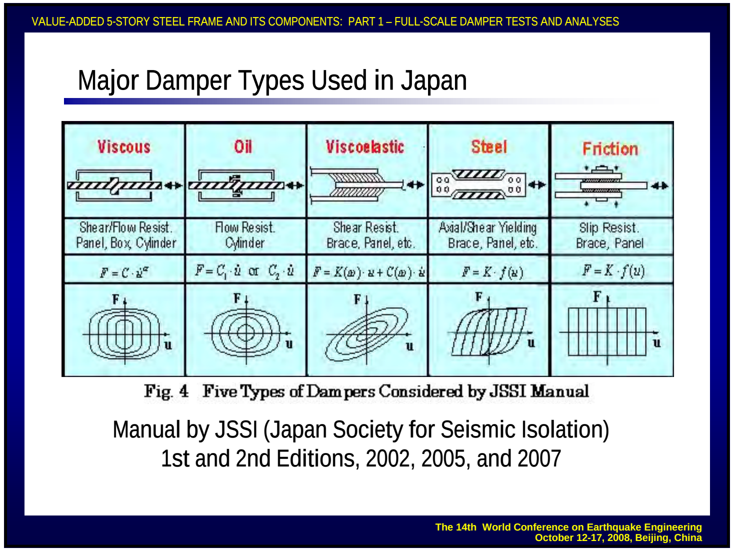
Beam-column strength ratio (bi-axially bent), and column width-to-thickness ratio are keys to avoid this disaster. Their effects must be studied for future design code. Analytical prediction must be improved, especially when dealing with instability or collapse.

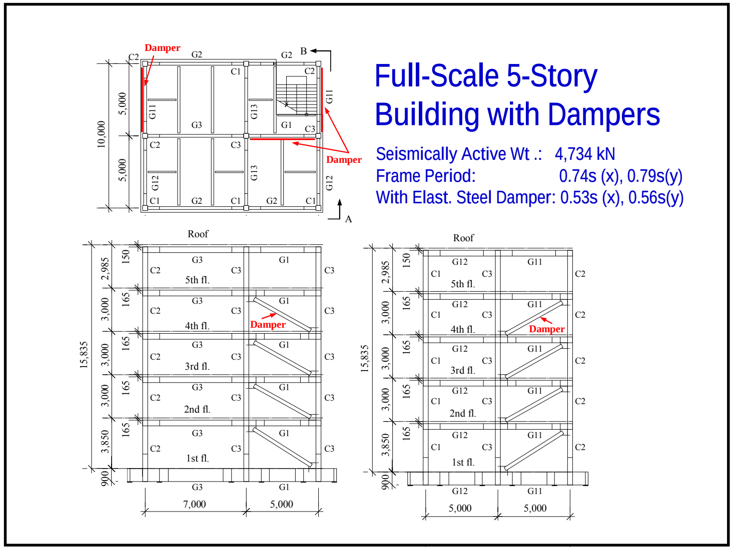
(2) Damper & Isolation Systems WG

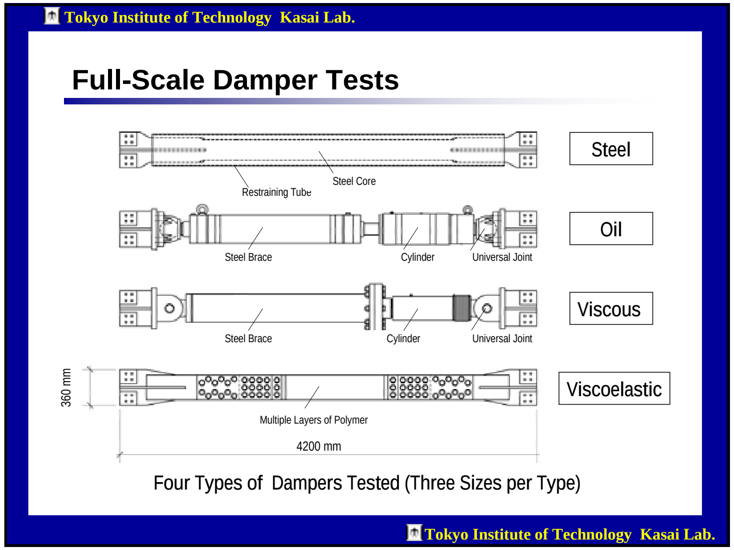
Because passively-controlled building has never experienced moderate to stronger earthquakes, conduct realistic tests using full-scale model, and

- Verify reliability of different damper types & sizes under in- & out-of-plane dispt.s of small to large magnitudes.
- Measure dynamic properties of the realistic building at various vibration levels (ambient, shaker, & shaking table).
- Confirm good protection of a Japanese conventional frame of similar height, which without damper can vibrate considerably.
- Calibrate and advance numerical simulation techniques. → Blind analysis contest

The tests produced 1447 channels of data (the largest in the history of E-Defense).


VALUE-ADDED 5-STORY STEEL FRAME AND ITS COMPONENTS: PART 1 – FULL-SCALE DAMPER TESTS AND ANALYSES
Major Damper Types Used in Japan
Viscous
Oil
Viscoelastic
Steel
Friction
Shear/Flow Resist. Panel, Box, Cylinder
Flow Resist. Cylinder
Shear Resist. Brace, Panel, etc.
Axial/Shear Yielding Brace, Panel, etc.
Slip Resist. Brace, Panel
Fig. 4 Five Types of Dampers Considered by JSSI Manual
Manual by JSSI (Japan Society for Seismic Isolation)
1st and 2nd Editions, 2002, 2005, and 2007
The 14th World Conference on Earthquake Engineering
October 12-17, 2008, Beijing, China


Full-Scale 5-Story
Building with Dampers
Seismically Active Wt.: 4,734 kN
Frame Period: 0.74s (x), 0.79s(y)
With Elast. Steel Damper: 0.53s (x), 0.56s(y)
Damper
Roof
5th fl.
4th fl.
3rd fl.
2nd fl.
1st fl.


Tokyo Institute of Technology Kasai Lab.
Full-Scale Damper Tests
Steel
Oil
Viscous
Viscoelastic
Restraining Tube
Steel Core
Steel Brace
Cylinder
Universal Joint
Multiple Layers of Polymer
360 mm
4200 mm
Four Types of Dampers Tested (Three Sizes per Type)
Tokyo Institute of Technology Kasai Lab.

Full-Scale 5-Story Building with Steel Dampers

Steel Dampers

Viscous Dampers

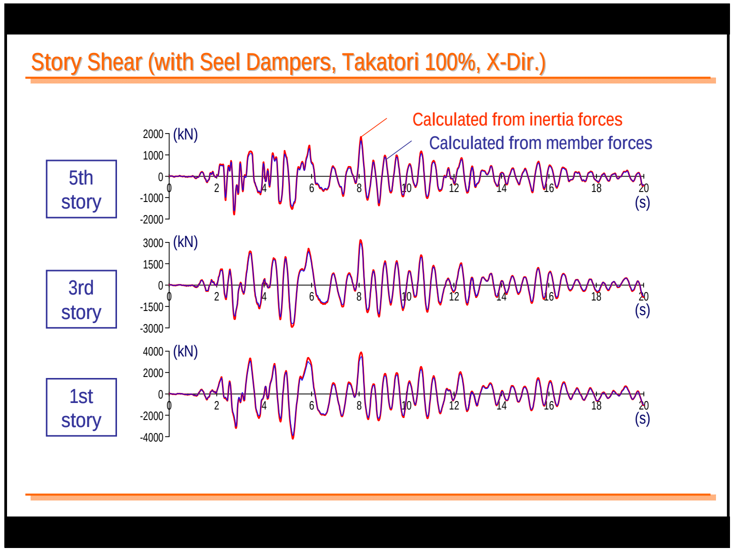
Oil Dampers

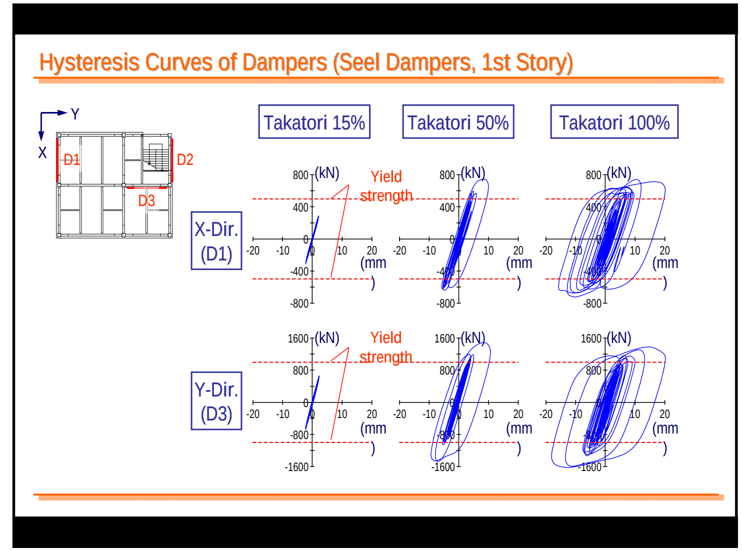
Viscoelastic Dampers

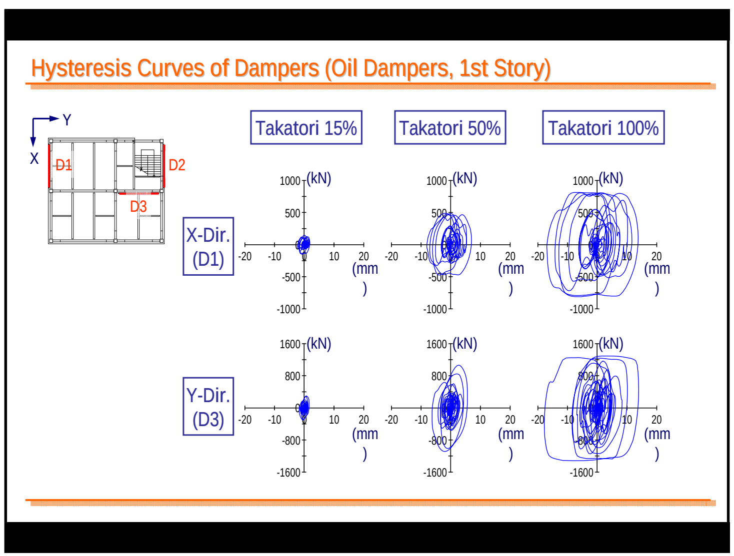

TCR 15:29.38.24

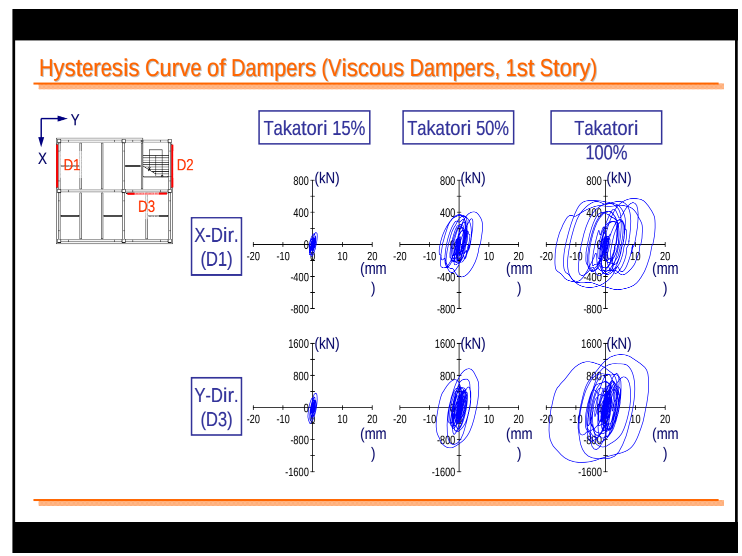

TCR 15:07.14.08

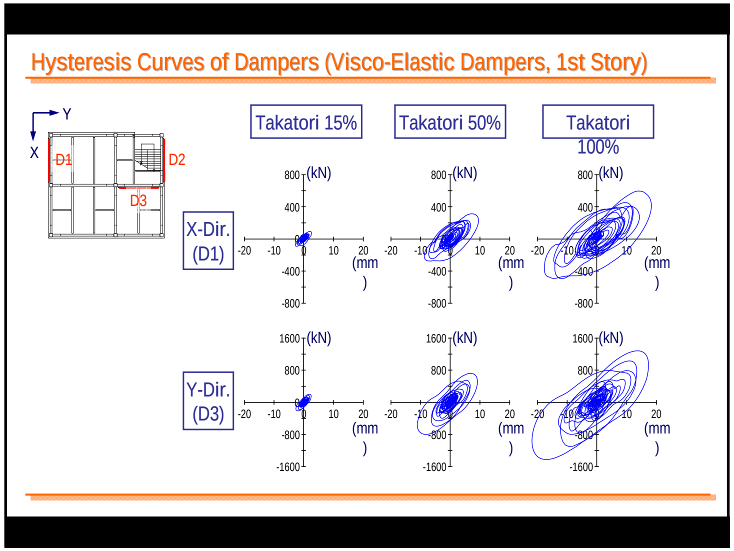

Tokyo Institute of Technology Kasai Lab.
Tests Using Shakers
(Vibration Generators)
Tokyo Institute of Technology Kasai Lab.

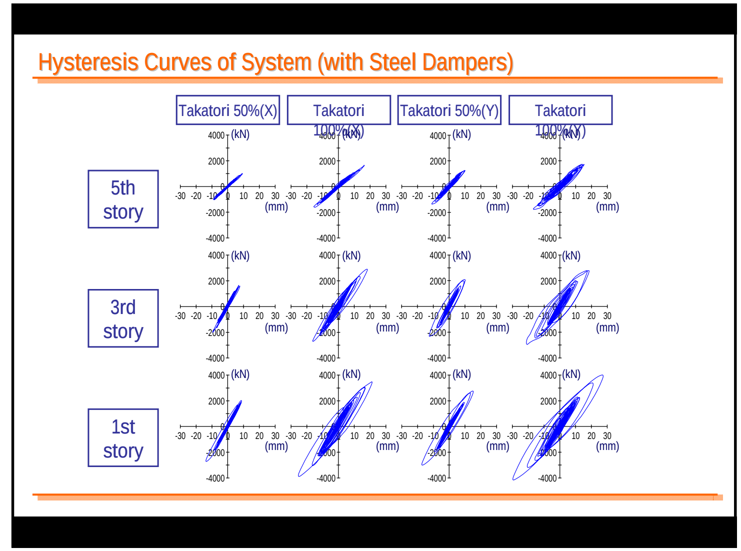

Story Shear (with Seel Dampers, Takatori 100%, X-Dir.)
Calculated from inertia forces
Calculated from member forces
5th story
3rd story
1st story
(kN)
(s)

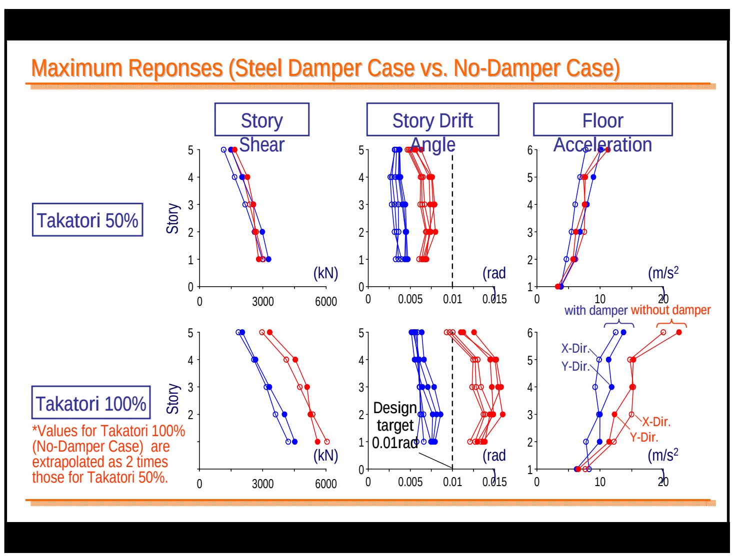

Hysteresis Curves of Dampers (Seel Dampers, 1st Story)
Takatori 15%
Takatori 50%
Takatori 100%
X-Dir. (D1)
Y-Dir. (D3)
Yield strength
D1
D2
D3
X
Y
(kN)
(mm)

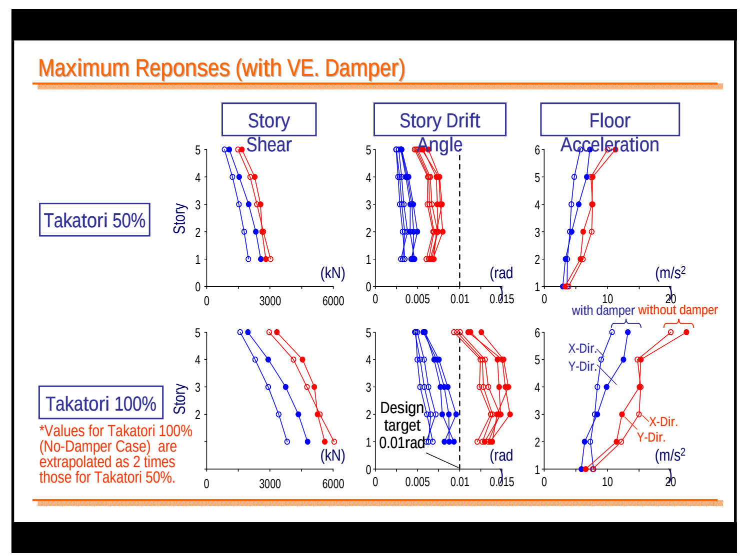

Hysteresis Curves of Dampers (Oil Dampers, 1st Story)
Takatori 15%
Takatori 50%
Takatori 100%
X-Dir. (D1)
Y-Dir. (D3)
D1
D2
D3
X
Y
(kN)
(mm)


Hysteresis Curve of Dampers (Viscous Dampers, 1st Story)
Takatori 15%
Takatori 50%
Takatori 100%
X-Dir. (D1)
Y-Dir. (D3)
D1
D2
D3
X
Y
(kN)
(mm)


Hysteresis Curves of Dampers (Visco-Elastic Dampers, 1st Story)
Y
X
D1
D2
D3
Takatori 15%
Takatori 50%
Takatori 100%
X-Dir.
(D1)
Y-Dir.
(D3)
(kN)
(mm)


Hysteresis Curves of System (with Steel Dampers)
Takatori 50%(X)
Takatori 100%(X)
Takatori 50%(Y)
Takatori 100%(Y)
5th story
3rd story
1st story
(kN)
(mm)


Maximum Reponses (Steel Damper Case vs. No-Damper Case)
Story Shear
Story Drift Angle
Floor Acceleration
Takatori 50%
Takatori 100%
Story
(kN)
(rad
(m/s2
with damper
without damper
X-Dir.
Y-Dir.
Design target 0.01rad
*Values for Takatori 100% (No-Damper Case) are extrapolated as 2 times those for Takatori 50%.


Maximum Reponses (with VE. Damper)
Story Shear
Story Drift Angle
Floor Acceleration
Takatori 50%
Takatori 100%
Story
(kN)
(rad
(m/s2
with damper
without damper
X-Dir.
Y-Dir.
Design target 0.01rad
*Values for Takatori 100% (No-Damper Case) are extrapolated as 2 times those for Takatori 50%.

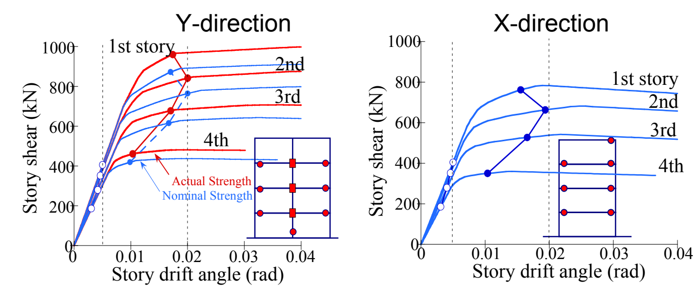
Conclusions and Future Studies
(Damper & Isolation Systems WG)

The bldg. with all 4 damper types performed well under design basis & catastrophic earthqs. Since frame members remained almost elastic and dampers could be modeled by clear math. equations, analysis was more accurate than collapse case.

Using the test data, design & analysis scheme will be verified and improved. Cases of frame member yielding, and ultimate state must be studied by applying even stronger quakes.

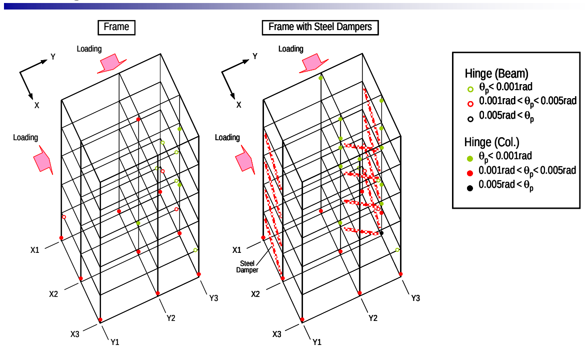
(3) Analysis WG

38



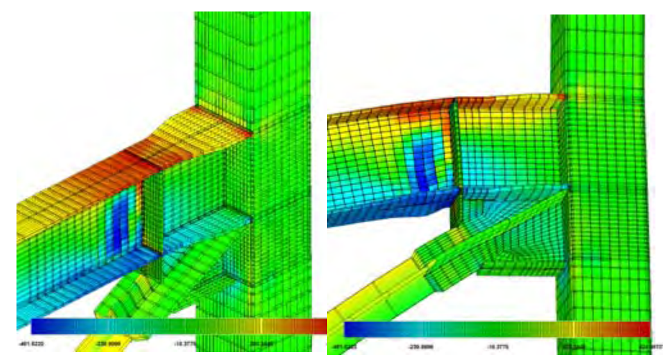
- Extensive pre-test analyses in order to get good test results.
- Post-test analyses to under stand test results are on-going, using various methods.

Analytical Simulations



Plastic Hinges Produced Due to Simultaneous Loading
(At Story Drift Angle of 1/75 rad.)

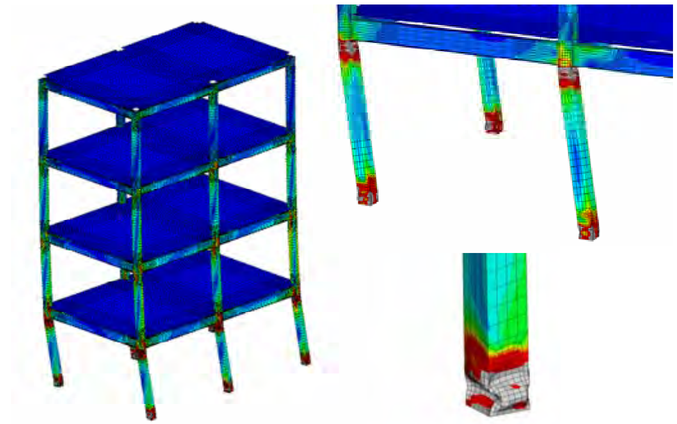
Analysis of Beam-Column-Damper Connection



(a) Beam Longitudinal Stress (b) Deformation Enlarged (x10)

E-Defense Steel Research Project, First & Second Years

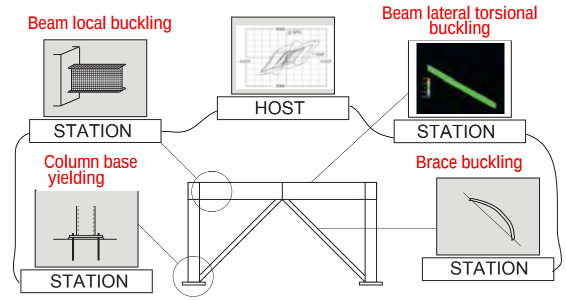
Time history analysis (1.3 x Takatori)



E-Defense Steel Research Project, First & Second Years

E-Defense Steel Research Project, First & Second Years

Collaborative Structural Analysis (see example below) was also performed.



- STATION deals with detailed analysis of component
- HOST put together results from STATIONS by internet, and do step-by-step analysis.

E-Defense Steel Research Project, First & Second Years

Blind Analysis Contest

- We also held 2007 Blind Analysis Contest for Prediction of Pre-Collapse and Collapse Responses :
  52 Teams Submitted
  (US:14, Japan:20, China:6, Taiwan:8, Others:4)
- Announced results (4 Categories) in Dec. , 2007.
  Winning teams were from Japan, US, and Taiwan.
- Invited 4 winners to 14th World Conference on Earthquake Engineering (14WCEE) in 2008.
- Honored the winners in the International Collaboration Session of the 14WCEE.

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Blind Analysis Contest for Response (& Collapse) Prediction

On-Going Blind Analysis Contest for Steel Damper Case and Viscous Damper Case

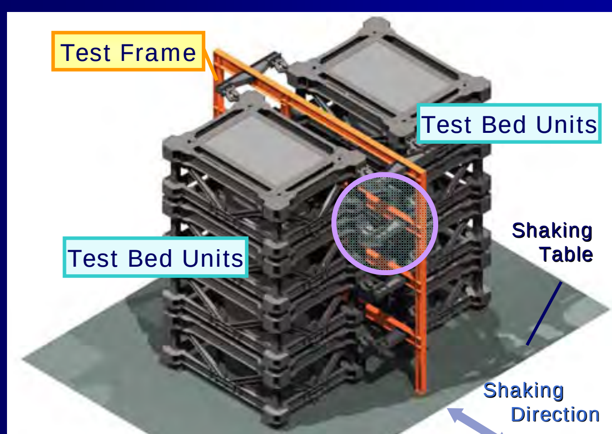
(4) Test Bed WG

Develop a convenient test system that enables economical tests to load a large-scale 2D-frame by using E-Defense.

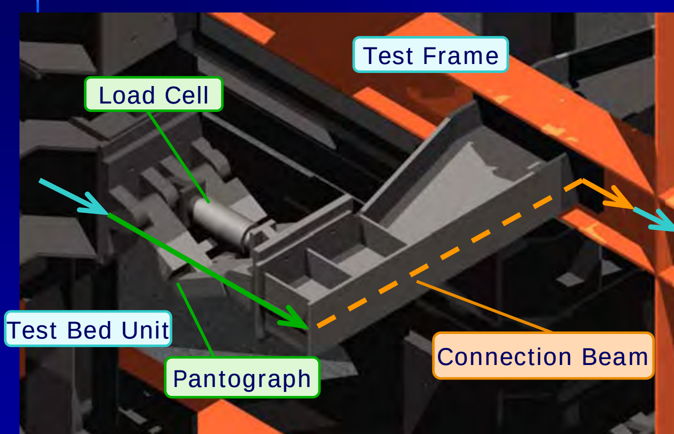
Examine dynamic properties of the test bed, and confirm its appropriateness as the generator of horizontal inertia force against the frame specimen.

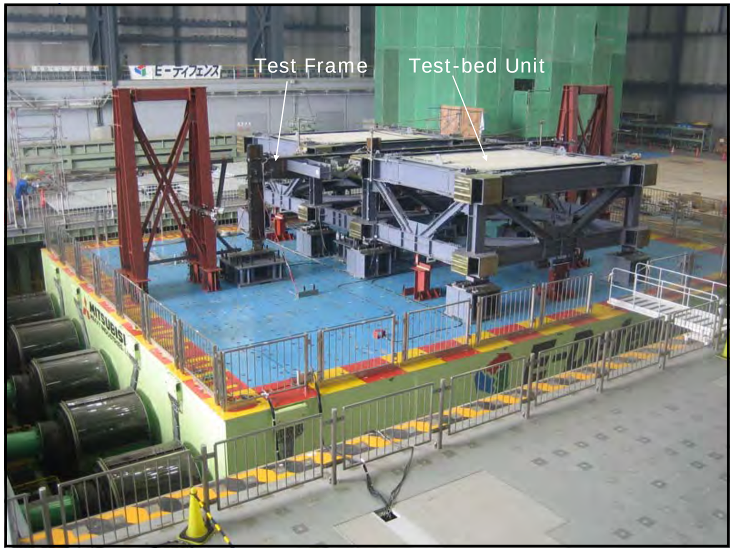
Collaborating with the NEES researchers, use the test bed to find performance of the innovative rocking system that is attracting attention from academic and engineering communities of US and Japan.

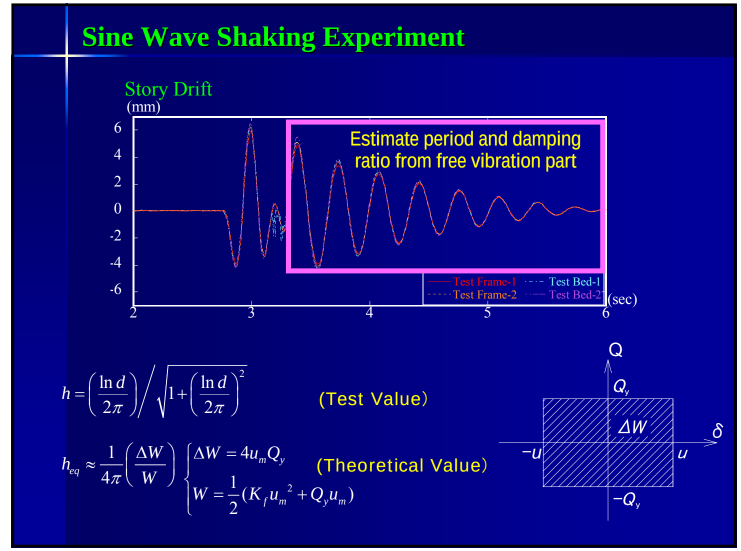
Basic Layout

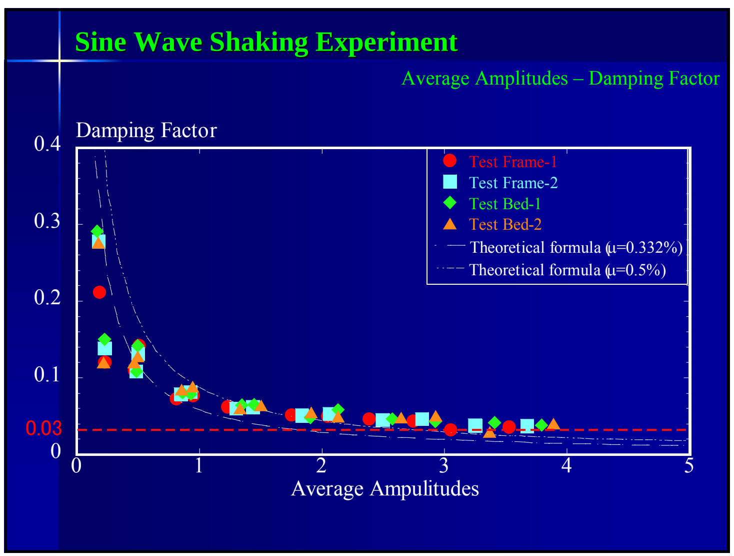


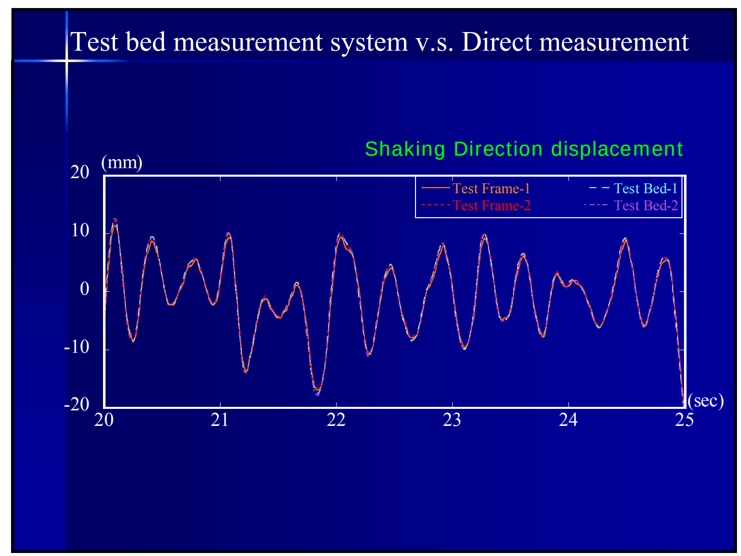
Connection Between Test Frame & Test Bed Unit




Test Frame
Test-bed Unit


Sine Wave Shaking Experiment
Story Drift
(mm)
Estimate period and damping ratio from free vibration part
Test Frame-1
Test Frame-2
Test Bed-1
Test Bed-2
(sec)
$h = \left(\frac{\ln d}{2\pi}\right) \Big/ \sqrt{1+\left(\frac{\ln d}{2\pi}\right)^2}$
(Test Value)
$h_{eq} \approx \frac{1}{4\pi}\left(\frac{\Delta W}{W}\right)$ $\Delta W = 4u_m Q_y$, $W = \frac{1}{2}(K_f u_m^2 + Q_y u_m)$
(Theoretical Value)
Q
Q_y
ΔW
δ
$-u$
u
$-Q_y$


Sine Wave Shaking Experiment
Average Amplitudes – Damping Factor
Damping Factor
Test Frame-1
Test Frame-2
Test Bed-1
Test Bed-2
Theoretical formula (μ=0.332%)
Theoretical formula (μ=0.5%)
0.03
Average Amplitudes


Test bed measurement system v.s. Direct measurement
Shaking Direction displacement
(mm)
Test Frame-1
Test Frame-2
Test Bed-1
Test Bed-2
(sec)

NEESR-SG: Controlled Rocking of Steel-Framed Buildings with Replaceable Energy Dissipating Fuses

LARGE-SCALE TESTING AT E-DEFENSE – 65% OF JMA KOBE

Gregory G. Deierlein, Sarah Billington, Helmut Krawinkler, Xiang Ma, Alejandro Pena, Eric Borchers, *Stanford University*

Jerome F. Hajjar, Matthew Eatherton, Noel Vivar, Kerry Hall, *University of Illinois*

Toru Takeuchi, Kazuhiko Kasai, and Shoichi Kishiki, *Tokyo Institute of Technology*

Mitsumasa Midorikawa and Tetsuhiro Asari, *Hokkaido University*

Tsuyoshi Hikino, *Hyogo Earthquake Engineering Research Center, NIED*

David Mar, *Tipping & Mar Associates* and **Greg Luth**, *GPLA*

E-Defense

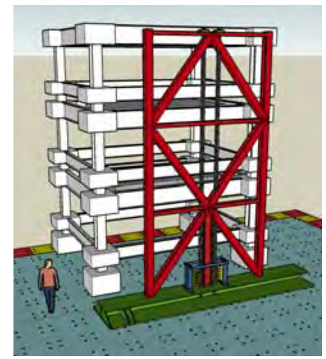
JISF

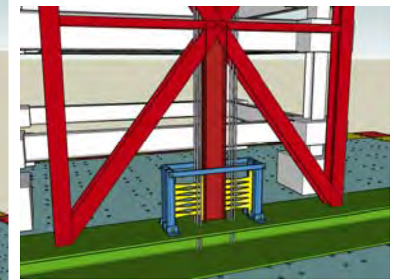
In-Kind Funding: **Tefft Bridge and Iron** of Tefft, IN, **MC Detailers** of Merrillville, IN, **Munster Steel Co. Inc.** of Munster, IN, **Infra-Metals** of Marseilles, IN, and **Textron/Flexalloy Inc. Fastener Systems Division** of Indianapolis, IN., **Nippon Steel Engineering Company** of Tokyo, Japan

NEES

George E. Brown, Jr. Network for Earthquake Engineering Simulation

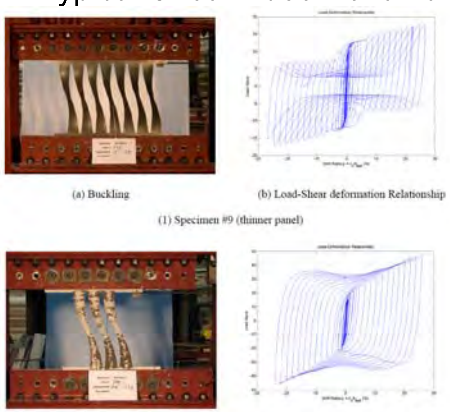
Rocking Frame Specimen – Single Frame





Member size and panel connection detail doesn't reflect current design

Typical Shear Fuse Behavior



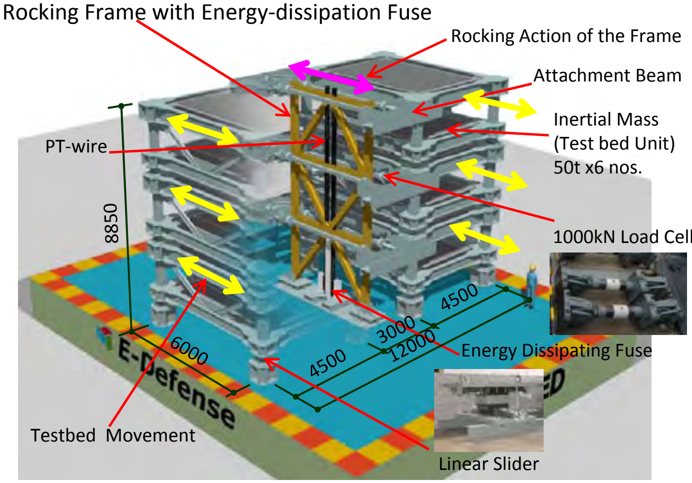
(a) Buckling (b) Load-Shear deformation Relationship

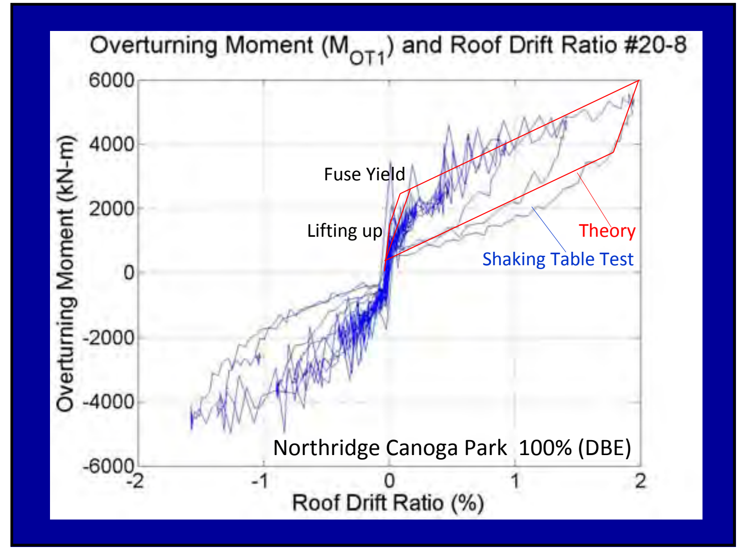
(1) Specimen #9 (thinner panel)

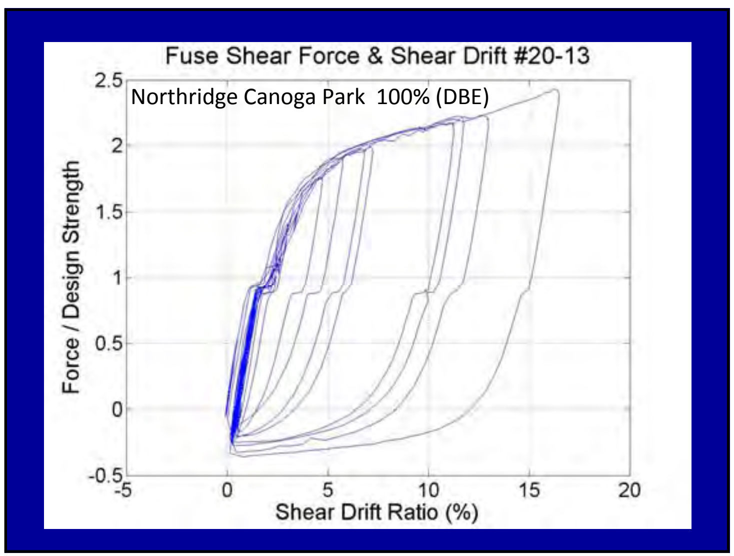
(a) Large bending Deformation (b) Load-Shear deformation Relationship

(2) Specimen #11 (thicker panel)

- Degrading
- Non-Degrading







US-Japan Meeting Dates (Rocking Frame)

2008.4	ASCE Structures Congress, Vancouver
2008.7	Webex Meeting
2008.9	Univ. of Illinois, Urbana-Champaign
2008.10	14WCEE, Beijing
2008.12	Webex Meeting
2009.3	NIED, E-Defense
2009.4	Webex Meeting
2009.7	Skype Meeting
2009.7	Skype Meeting
2009.7	Ma & Deierlein (Stanford) and Hajjar & Eatherton (UIUC) begin staying for more than 1 month.
2009.8	Tests at NIED, E-Defense

Note: Japanese team meeting was held almost every month for 2.5 years.

Work sharing between US and Japan

- US
  (1) Preliminary design of rocking frame
  (2) Static tests of fuses and large-scale frames
  (3) Analysis
  (4) Payment for specimen, shaking fee, instrumentation
- Japan
  (1) Prepare all parts for the tests including Testbeds
  (2) BRB and PT-wire components tests
  (3) Final design matching to Japanese standard
  (4) Fabrication and assembly of test system
  (5) Shake table tests at E-Defense
  (6) Payment for assembly, shaking fee, instrumentation

Accounting (tentative)

No.	Items	US	JISF	NIED
1	Testbed and specimen assembling	-	-	$100,000
2	Fabricating Specimen	$130,000	$10,000	-
3	Instrumentation	$50,000	-	$50,000
4	Fuels	$80,000	-	$80,000
5	Fee for shaking table occupation	0	-	0
6	Steel plates setting to Testbeds	-	-	$20,000
7	PT-wire load cells	-	$10,000	-
8	Instrumentation Jigu	-	$10,000	$10,000
	TOTAL	$260,000	$30,000	$260,000

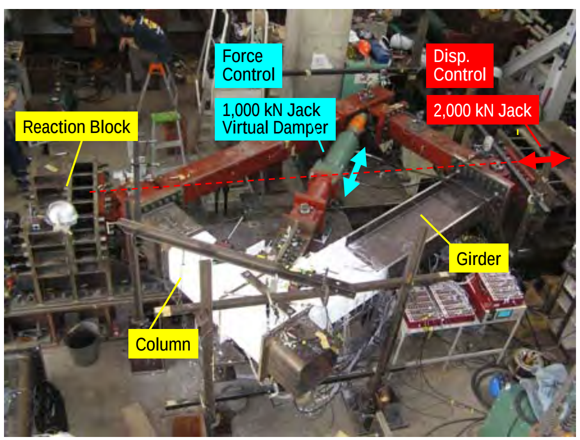
Note) 1$ = 90 Yen

Prof. Hajjar (Univ. IL), Profs. Krawinkler and Deierlein (Stanford Univ.)

Conclusions (Test Bed WG)

Long discussions for preparations, tough effort in assembling stage, and ropewalking operations in some shaking. However, I believe it was very successful, worthwhile and also it was nice experiences working together with good members from both countries.
I thank all of young members played on important functions, and valuable advices were given from professors (Takeuchi).

This project was a great collaboration. I especially appreciate how well the students worked well together and with the faculty and E-Defense staff. The successful outcome did not come by chance, but was the result of everyone's contributions during the planning, design and execution of the tests (Deierlein).



Subassembly Test Set-up

US/JPN Collaboration on Non-structural component tests using E-defense

2007.9 Preliminary meeting on Non-structural components

Date : March 3, 2008 at Tokyo
First meeting on policy for testing with E-defense

April, 2008 – March, 2009 via E-mail
Discussion on Construction or Measurement method for Ceiling

Date : March 31, 2009 at E-defense
Final meeting on detail of measurement

Date : April 6-7, 2009
Experiments done

US/JPN Collaboration on Non-structural component tests using E-defense

March 3, 2008 meeting

Outline of passively-controlled building test (Prof.Kasai; T.I.T)

Outline of nonstructural components tests by US group and Collaboration with E-defense (Prof. Maragakis; Navada Univ.)

Intro to Hilti business and research/regulation activities (Dr. Bourgund; Hilti)

Results of nonstructural components in the collapse test on last September (Mr.Matsuoka; E-defense)

Traditional style and recommended by JPN government style of ceiling (Prof. Motoyui; T.I.T.)

Sprinkler, Piping and Floor-isolation-system made by JPN companies (Prof. Mizutani; Tokyo Polytechnic Univ.)

Anchorage: previous large-scale test experience and potential E-defense research interests (Mr. Matthew; Hilti)

Discussion & group planning (Everyone)

Video Presentation

Ceiling Failure Test

April 6, 2009

US/JPN Collaboration on Non-structural component tests using E-defense

THE END

Shaking Schedule

Date	FUSE	Wave & Level
8/6(Thu)	A0(PL-22)	JMA Kobe-DBE(46.1%)
8/7(Fri)	A0(PL-22)	Northridge-DBE(95%)
8/10(Mon)	A1(PL-22)	JMA Kobe-MCE(69.1%)
8/14(Fri)	BRB	JMA Kobe-MCE(69.1%)
8/19(Wed)	B(PL-6×2)	JMA Kobe-MCE(69.1%)
8/24(Mon)	A2(PL-22)	Northridge-MCE(140%)

Preliminary Experiments

No.	Experiments		Period	Location
1	FUSES Experiments	US	2007	Stanford University
2	Basic property Experiments of Test bed	Japan	March 2007	NIED, E-Defense
3	Preliminary Experiments of Test bed	Japan	July 2007	NIED, E-Defense
4	Large-Scale Experiments (quasi-static)	US	August 2008 to March 2009	University of Illinois
5	Construction six Test beds	Japan	October 2008 to March 2009	NIED, E-Defense
6	Linear slider Components tests	Japan	May 2009	NIED, E-Defense
7	PT-wire Component tests	Japan	July 2009	Tokyo Institute of Technology
8	Buckling Restrain Brace Component tests	Japan	July 2009	Tokyo Institute of Technology

Joint Research Agreement

- Major Items
  (1) Period of Performance
  (2) Specific scope of work
  (3) Individuals Engaged in Joint Research
  (4) Estimated Cost
  (5) Intellectual Property
  (6) Data sharing concept
  (7) Confidentiality
  (8) Reports
  (9) Billing
  (10) Insurance
  (11) Termination
  (12) Certification of Trustworthy Association
  (13) Laws and Regulations

Large Scale Tests of High-Rise Buildings

National Research Institute for Earth Science and Disaster Prevention

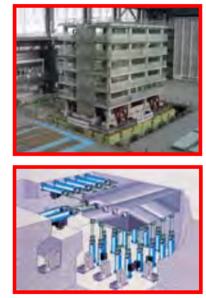
High-Rise Buildings

Safety of Room

Introduction

Today's Test

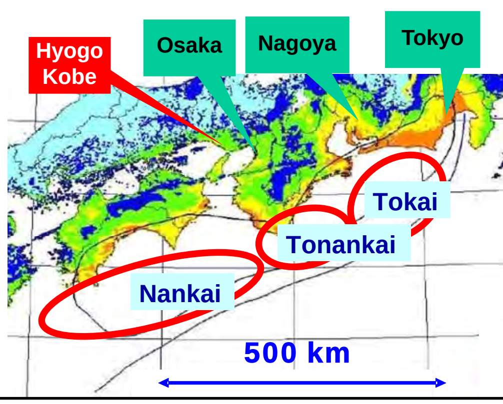
Performance of frame



E-Defense

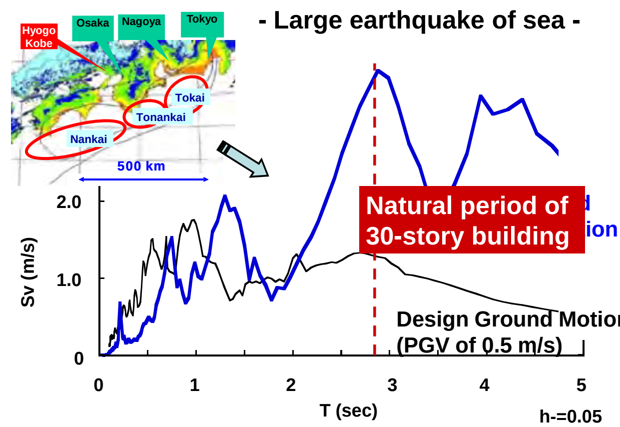
Subduction Type of Earthquake

- Periodical occurrence -



Long Period Ground Motion

- Large earthquake of sea -



Rooms

-Disaster Prevention Enlightenment-

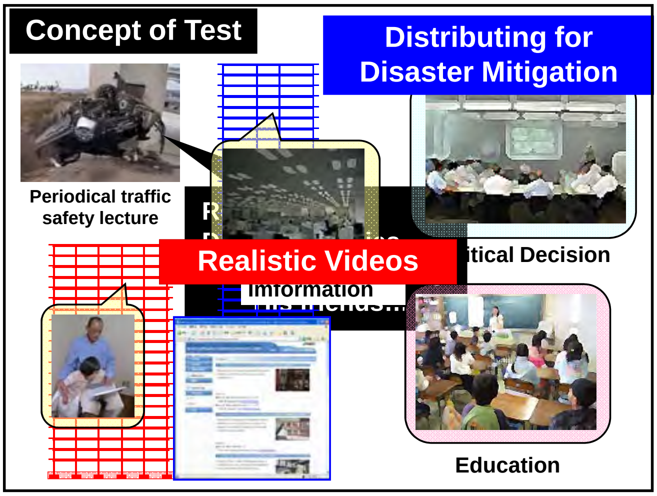
Seismic Response

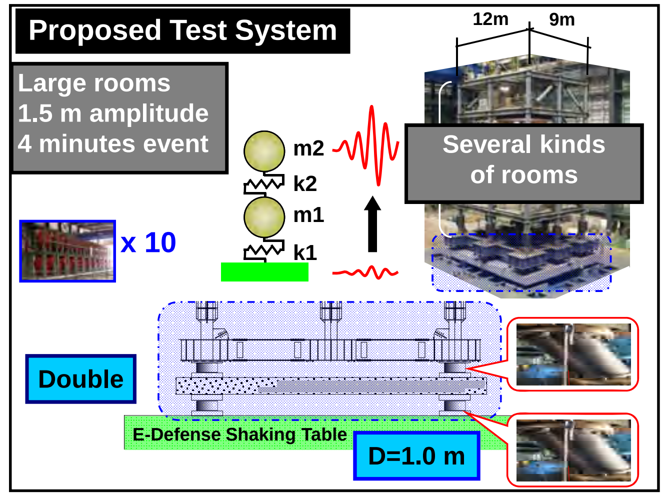
How we can explain such situation?

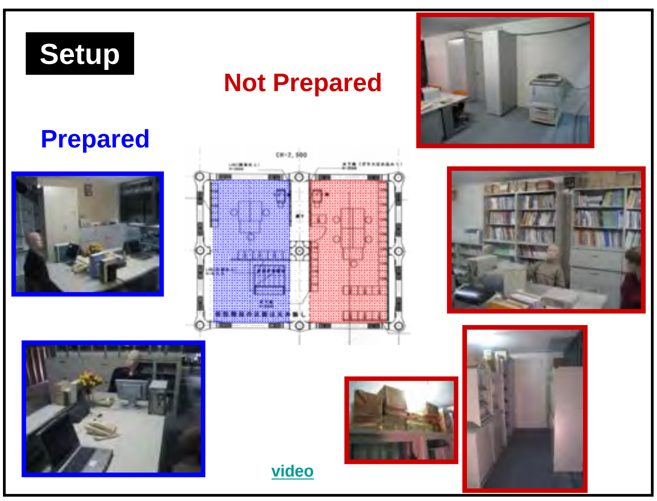
Rooms become very dangerous.

Have we seen such responses?

Numerical Model

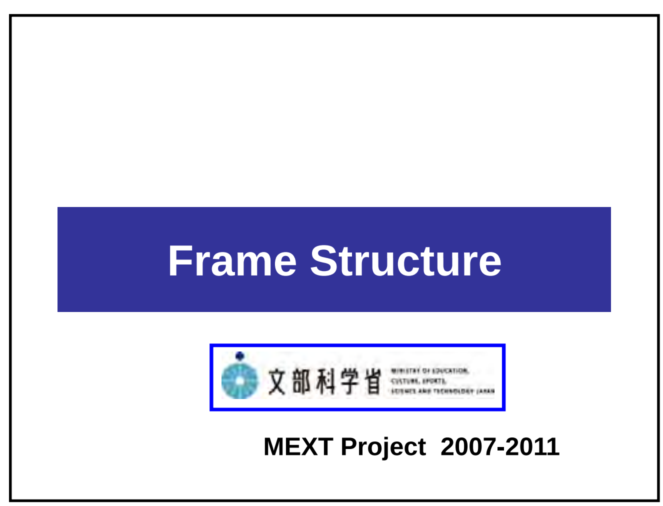

Concept of Test
Distributing for
Disaster Mitigation
Periodical traffic
safety lecture
Realistic Videos
itical Decision
Information
Education

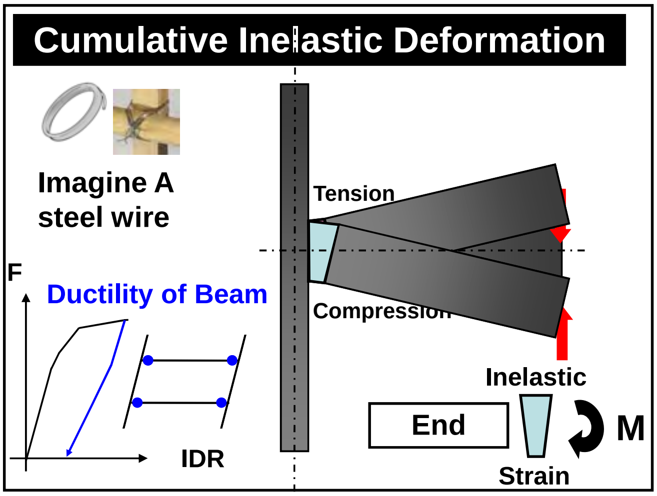

Proposed Test System
12m
9m
Large rooms
1.5 m amplitude
4 minutes event
m2
k2
m1
k1
Several kinds
of rooms
x 10
Double
E-Defense Shaking Table
D=1.0 m

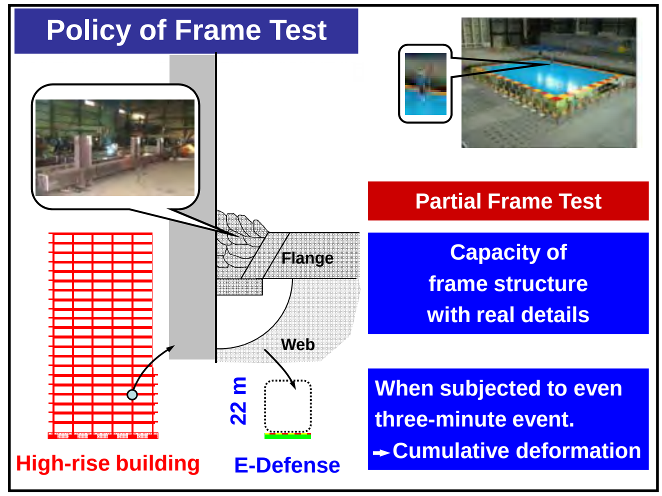

Setup
Not Prepared
Prepared
video

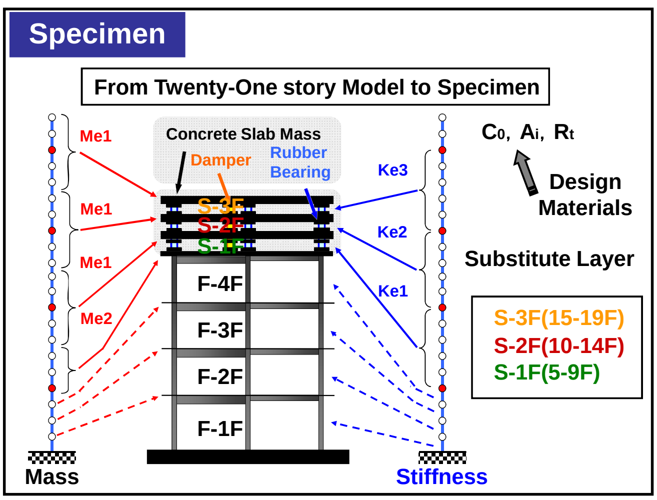

Kitchen
Not Prepared
Prepared

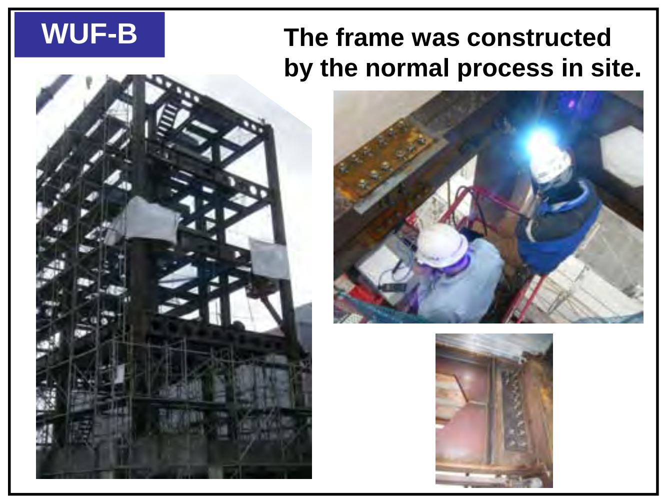

New tool for enlightening
Preparations drastically change the damage
http://www.bosai.go.jp/hyogo/ehyogo/movie.html
Tokyo government made
strict regulations
after seeing the videos


Frame Structure
文部科学省
MEXT Project 2007-2011

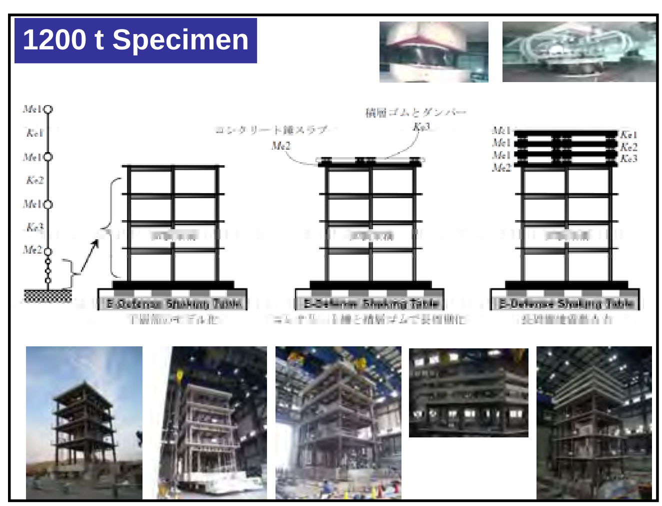

Cumulative Inelastic Deformation
Imagine A steel wire
F
Ductility of Beam
IDR
Tension
Compression
Inelastic
End
M
Strain

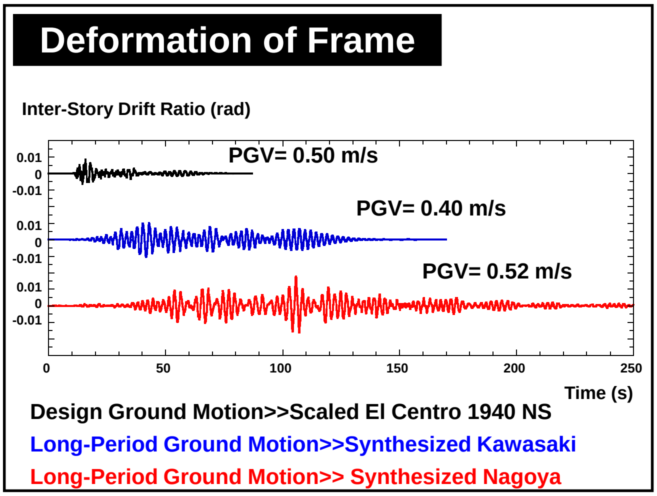

Policy of Frame Test
Flange
Web
22 m
High-rise building
E-Defense
Partial Frame Test
Capacity of frame structure with real details
When subjected to even three-minute event.
→Cumulative deformation

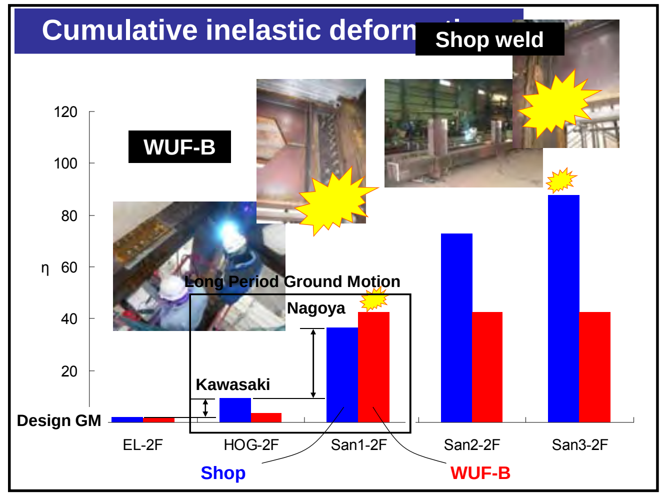

Specimen
From Twenty-One story Model to Specimen
Me1
Me1
Me1
Me2
Concrete Slab Mass
Damper
Rubber Bearing
Ke3
Ke2
Ke1
S-3F
S-2F
S-1F
F-4F
F-3F
F-2F
F-1F
C0, Ai, Rt
Design Materials
Substitute Layer
S-3F(15-19F)
S-2F(10-14F)
S-1F(5-9F)
Mass
Stiffness

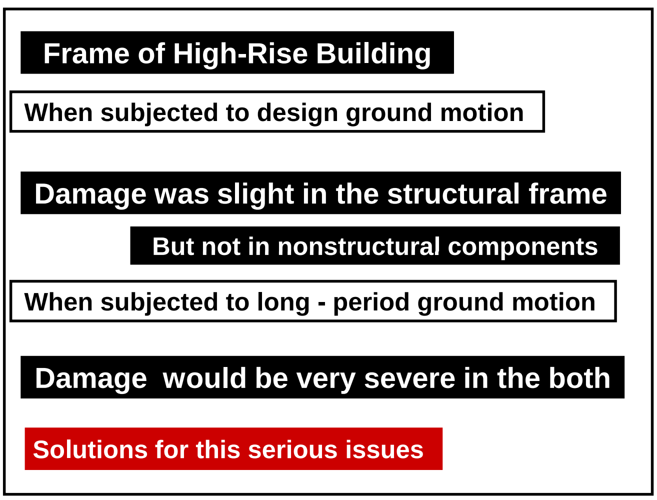

WUF-B
The frame was constructed by the normal process in site.

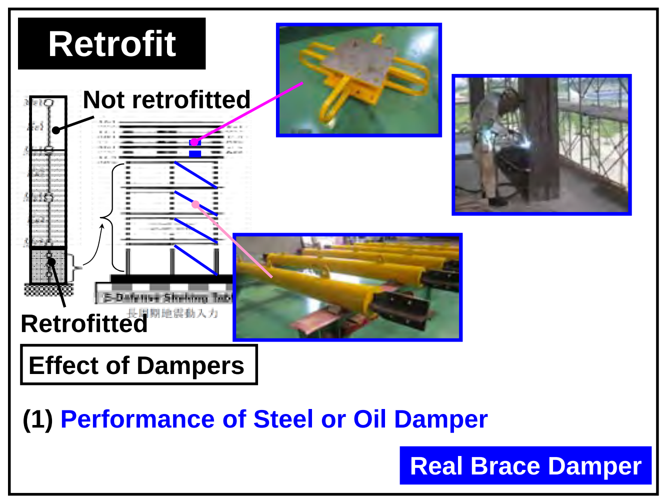

RC Slab
D13@200
D10@100
Stud 19ϕL=80@150

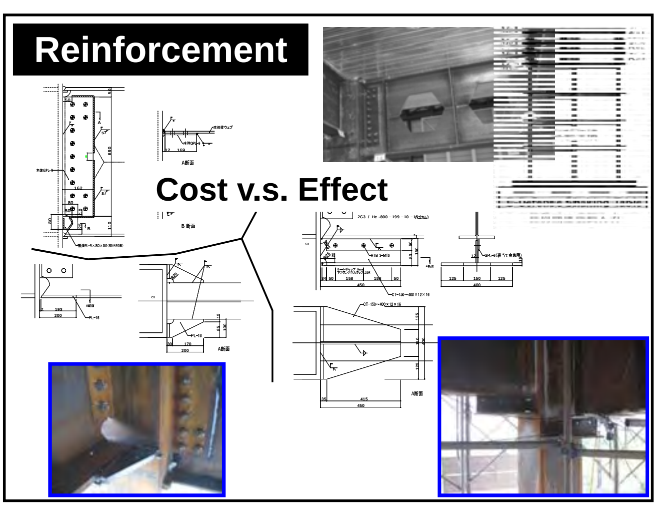

1200 t Specimen

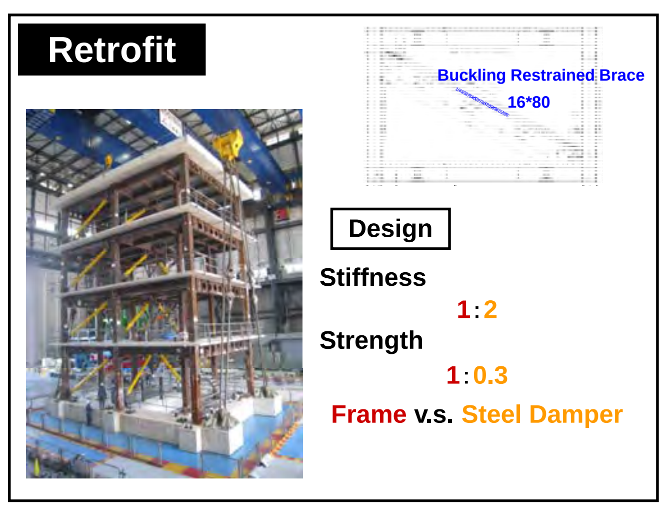

Deformation of Frame
Inter-Story Drift Ratio (rad)
PGV= 0.50 m/s
PGV= 0.40 m/s
PGV= 0.52 m/s
0.01
0
-0.01
0
50
100
150
200
250
Time (s)
Design Ground Motion>>Scaled El Centro 1940 NS
Long-Period Ground Motion>>Synthesized Kawasaki
Long-Period Ground Motion>> Synthesized Nagoya

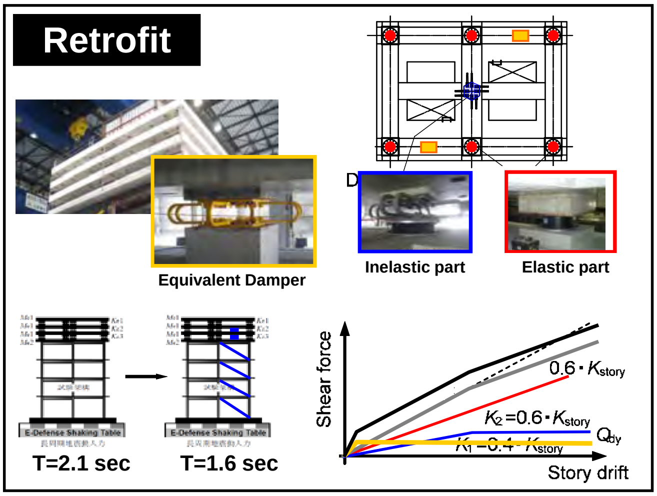

Cumulative inelastic deform
Shop weld
WUF-B
120
100
80
η 60
40
20
Long Period Ground Motion
Nagoya
Kawasaki
Design GM
EL-2F
HOG-2F
San1-2F
San2-2F
San3-2F
Shop
WUF-B

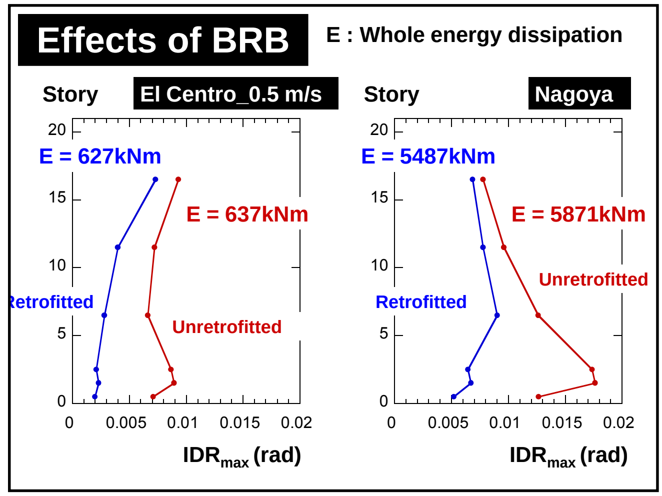

Frame of High-Rise Building
When subjected to design ground motion
Damage was slight in the structural frame
But not in nonstructural components
When subjected to long - period ground motion
Damage would be very severe in the both
Solutions for this serious issues

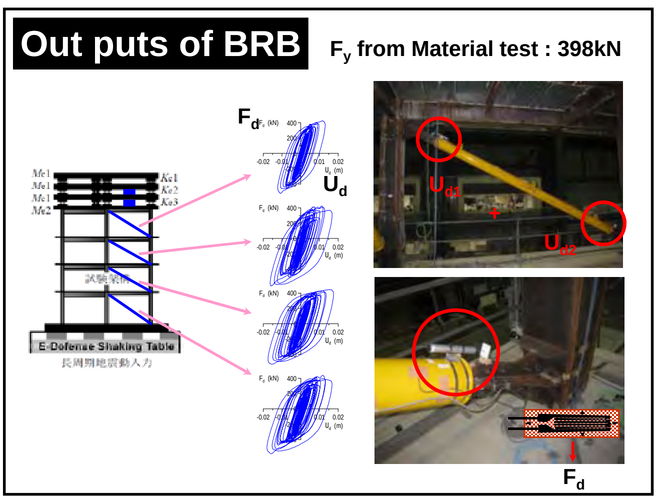

Retrofit
Not retrofitted
Retrofitted
Effect of Dampers
(1) Performance of Steel or Oil Damper
Real Brace Damper


Reinforcement
Cost v.s. Effect


Retrofit
Buckling Restrained Brace
16*80
Design
Stiffness
1:2
Strength
1:0.3
Frame v.s. Steel Damper


Retrofit
Equivalent Damper
Inelastic part
Elastic part
T=2.1 sec
T=1.6 sec
Shear force
Story drift
0.6・K_story
K2=0.6・K_story
K1=0.4・K_story
Qdy
E-Defense Shaking Table


Effects of BRB
E : Whole energy dissipation
Story
El Centro_0.5 m/s
Story
Nagoya
E = 627kNm
E = 637kNm
Retrofitted
Unretrofitted
E = 5487kNm
E = 5871kNm
Unretrofitted
Retrofitted
IDRmax (rad)
IDRmax (rad)


Out puts of BRB
Fy from Material test : 398kN
Fd
Ud
Ud1
Ud2
Fd
E-Defense Shaking Table


Participants
兵庫県
文部科学省
兵庫県立東播工業高等学校
社団法人兵庫県建築士会
DPRI
KOBE UNIVERSITY
名古屋大学
東京理科大学
Tokyo University of Science
竹中工務店
OBAYASHI
鹿島
清水建設
TAISEI

New Research Project Plan

Project (a) : New Materials and New Technologies

Taizo Matsumori, Takuya Nagae

Senior Researcher

Hyogo Earthquake Engineering Research Center,

National Research Institute for Earth Science and Disaster Prevention (NIED, JAPAN)

7th NEES/E-Defense Planning Meetings, September 18-19, 2009

Review of Dai-Dai-Toku Project (2005,2006)

6-story collective house

- Brittle shear failure of short columns
- Story mechanism due to higher modes
- Lateral load carrying capacity much higher than code specified calculation
- Distribution of shear into wall and frame

A pair of 3-story school buildings

- Effect of strengthening with attached steel frames
- Simulation of progressive collapse
- Fail-safe design against extreme motions
- Input energy loss with swaying base foundation

keywords : old specifications, collapse behavior, shear failure of short columns

Project (a) : New Materials and New Technologies

Main Activity — *Keywords : R/C structure, New construction, Resilient city*

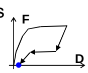
Verify seismic performance of new reinforced concrete structures by using E-Defense shaking table.

Research Topic

Current standard v.s. New materials, new technology

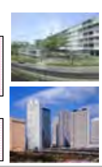
Current standard
- Damage of beam hinges
- Failure of beam-column joints
- Failure of various types of walls
- Ultimate capacities of columns
- Residual deformations

New materials, new technology
- High-strength materials
- High-performance walls
- Self-centering systems
- Improved nonstructural components



A) Medium-rise or low-rise building -> Next year

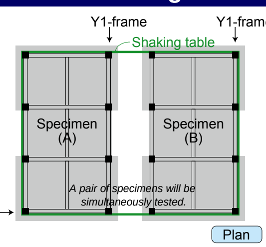
B) High-rise building -> Future

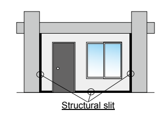


Testing Plan 1

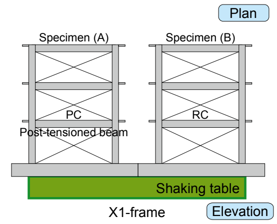
3 or 4-story building

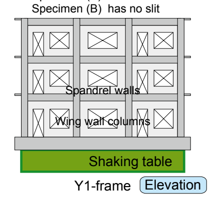
High strength cocrete F_c = 60 N/mm²





Specimen (A) has slits
Specimen (B) has no slit

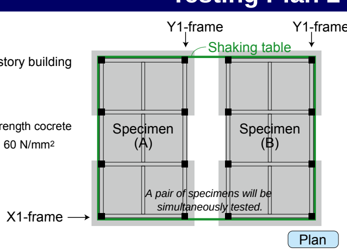


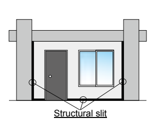


Testing Plan 2

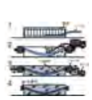
3 or 4-story building

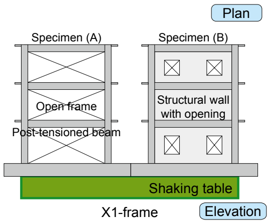
High strength cocrete F_c = 60 N/mm²

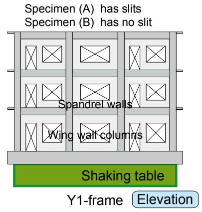




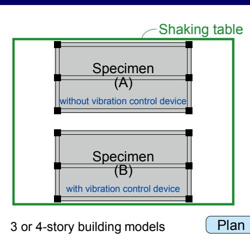
Specimen (A) has slits
Specimen (B) has no slit







Testing Plan 3

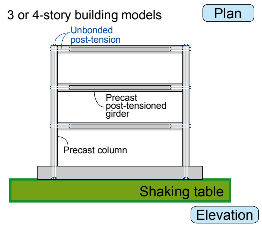


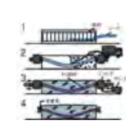
3 or 4-story building models

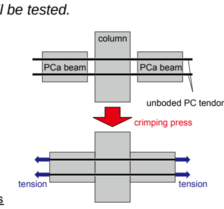
Unbonded Precast Prestressed Concrete Structure

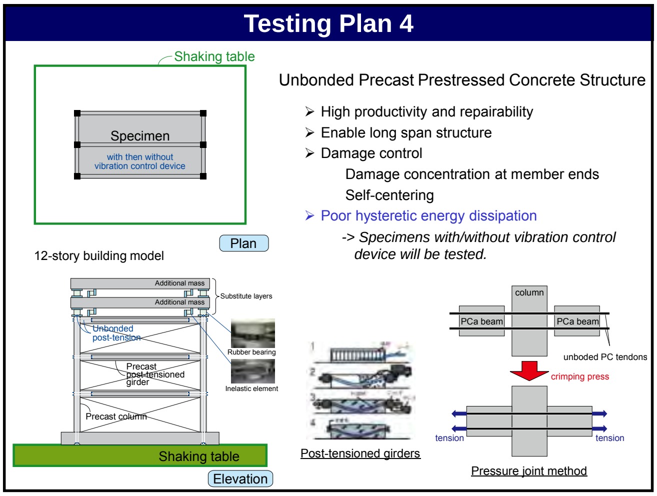
- High productivity and repairability
- Enable long span structure
- Damage control
  - Damage concentration at member ends
  - Self-centering
- Poor hysteretic energy dissipation

-> Specimens with/without vibration control device will be tested.

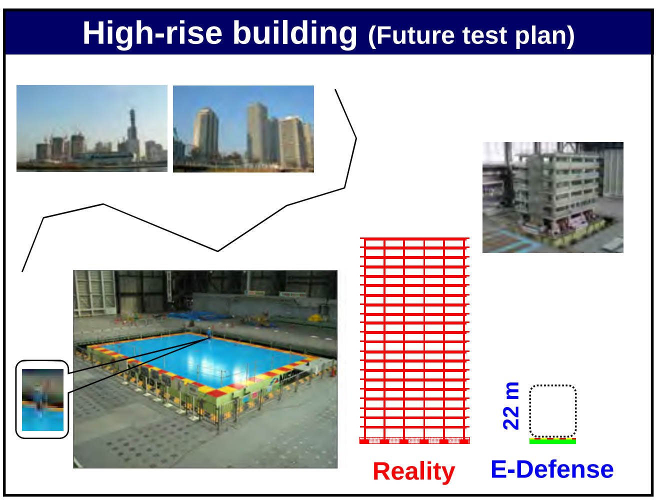


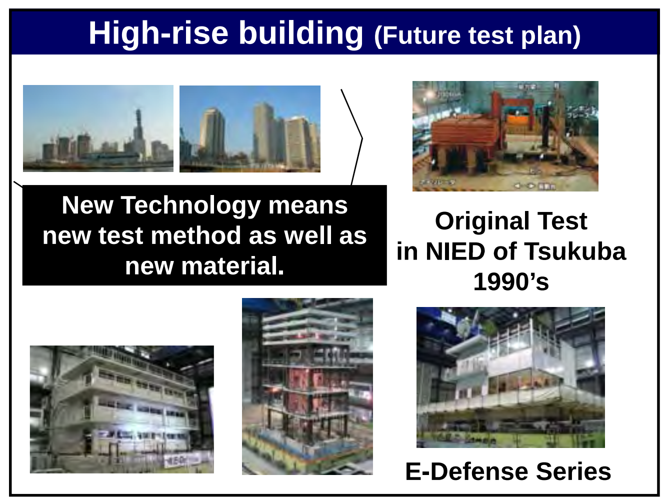





Testing Plan 4
Shaking table
Specimen
with then without
vibration control device
Plan
12-story building model
Additional mass
Additional mass
Substitute layers
Unbonded post-tension
Rubber bearing
Precast post-tensioned girder
Inelastic element
Precast column
Shaking table
Elevation
Unbonded Precast Prestressed Concrete Structure
High productivity and repairability
Enable long span structure
Damage control
Damage concentration at member ends
Self-centering
Poor hysteretic energy dissipation
-> Specimens with/without vibration control device will be tested.
Post-tensioned girders
column
PCa beam
PCa beam
unboded PC tendons
crimping press
tension
tension
Pressure joint method


High-rise building (Future test plan)
They have never experienced even design level GM.
Their seismic behaviors have never assessed in reality.


High-rise building (Future test plan)
22 m
Reality
E-Defense


High-rise building (Future test plan)
New Technology means new test method as well as new material.
Original Test in NIED of Tsukuba 1990's
E-Defense Series

New Research Project Plan

Project (b) : Base-isolation & Vibration Control

Eiji Sato, Kouichi Kajiwara

Senior Researcher

Hyogo Earthquake Engineering Research Center,

National Research Institute for Earth Science and Disaster Prevention (NIED, JAPAN)

7th NEES/E-Defense Planning Meetings, September 18-19, 2009

Background

- If a large earthquake occurs in an urban area, human damage and economical damage can become huge.
  - **11,000 dead** and **112 trillion yen** economic loss are estimated in Tokyo area.

⇩

- The goal is set to **halve the death toll** and to **reduce the economic loss by 40%** (by the Central Disaster Management Council)
- **BCP** etc. that aims to continue and to restore the business at the early stage during and after a disaster are paid to attention.

Background

- There's the fear that a long-period earthquake will occur.

⇩

- Serious damage to long-period structures such as seismic isolation buildings and high-rise buildings will be caused.

Patients room in a seismic isolation structure (after shaking tests)

Office in a high-rise building (after shaking tests)

Project (b): Base-isolation & Vibration Control

OUTLINE

Propose the next generation seismic isolation and vibration control systems which cope with long-period and short-period earthquake motions.

E-defense will prove the new proposing technology to apply to important city facilities.

(1) Hybrid seismic isolation with TMD or AMD

(2) Active or Semi-Active seismic isolation against long period earthquakes

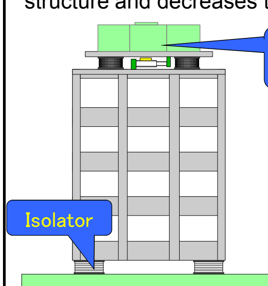
(3) Next generation 3D seismic isolation

(1) Hybrid seismic isolation with TMD or AMD

TMD or AMD is installed with a seismic isolation structure.

⇩

It controls the resonance phenomena of the seismic isolation structure and decreases the response acceleration.



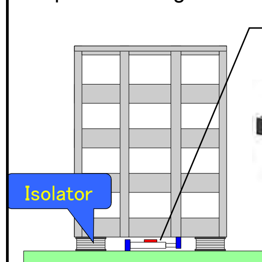
- Control of resonance phenomena
- Motion free in absolute space

(2) Active or Semi-Active seismic isolation against long period earthquake

Actuators or controllable dampers are installed with a seismic isolation structure.

⇩

It decreases the response acceleration and the relative displacement against long and short period earthquakes.



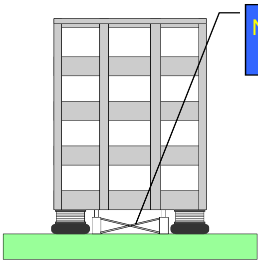
- Decrease of excessive relative displacement
- Motion free in absolute space

(3) Next generation 3D seismic isolation

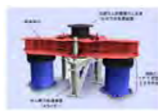
Propose a new 3D seismic isolator to applying to next generation 3D seismic isolation structures.

⇩

It decreases the vertical response acceleration to achieved high performance seismic isolation structures.



Next generation 3D seismic isolation including vertical isolator



Response reduction against vertical motion

Schedule

2010
- Investigation of application results and performance on existing technology
- Examination of control methods for high performance seismic isolation system
- Planning E-defense shaking table tests on the hybrid or the (semi) active seismic isolation system)

2011
- E-defense shaking table tests on the hybrid or the (semi) active seismic isolation system

2012
- Analysis of the shaking table tests data
- Preliminary examination of a New 3D seismic isolator
- Planning E-defense shaking table tests on the New 3D seismic isolation system

2013
- E-defense shaking table tests on the 3D seismic isolation system
- Conclusion

-fiscal year in Japan-

New Research Project Plan

Project (c) : Geotechnical Engineering Problems

Kentaro Tabata

Senior Researcher

Hyogo Earthquake Engineering Research Center

National Research Institute for Earth Science and Disaster Prevention

Reviews of geotechnical matters at E-Defense

- FY2005-06: Dai-Dai-Toku project years
  - Preparation of the containers, sand and measurement devices
  - Four tests performed = soil-pile-foundation interaction, liquefaction-induced lateral spreading phenomenon

E-Defense geotechnical testing

- Through the two-year process, recognize the E-Defense testing capability:
  - Reproduction of ground motion records on the table
  - Liquefaction and its influenced phenomena such as lateral spreading
  - Collapse of structures such as piles and caissons
  - Practice of model preparation and installation or setup of structures and sensors
- Two unique advantages of the E-Defense testing:
  - Large-scale model
    - > *Observe "more realistic" situations and phenomena*
  - Performance to produce earthquake disaster
    - > *Obtain the case histories of an "artificial" disaster*

"Resilient City" as a common meta-theme

- Achieve a disaster resilient city:
  - Importance to maintain lifelines' function during and even after a large earthquake or recover it quickly when damaged
- Especially in urban areas, widespread networks of buried, underground lifelines
  - < *Technology innovations, land shortage, landscape preservation…*
  - Large numbers, complex structures, deeper locations…
    - > *Behavior during earthquake?*
    - > *Evaluation method of their seismic capacity?*

Three types of investigations of seismic behavior

- In-situ damage investigations *after earthquake*
  - Actual behavior obtained = case history
- Numerical simulations *before/during/after earthquake*
  - Easy to conduct
  - Input parameters sensitive
  - 3-D analysis expensive
- Model tests *before/during/after earthquake*
  - Actual behavior of the models obtained
  - Scaling laws
  - Model preparation technique sensitive
    - > *Recall the E-Defense advantages: Large-scale models and performance to produce earthquake disaster*

Target of the future geotechnical research

- To achieve a disaster resilient city, need to maintain demanded performance of lifelines after a large earthquake
  - Keep the functions of lifelines during and after a large earthquake or recover it quickly when they damaged
- To fulfill the above, investigate their seismic behavior and develop methods to evaluate seismic capacity/performance
  - Lifeline structures in focus = transportation systems in an urban area
    - > *subway, railroad, expressway...*
    - > *underground structures such as tunnels and stations*

Research plans

- Perform E-Defense tests on seismic behavior of underground lifeline structures
  - Assume a subway station or expressway tunnel
  - Investigate behaviors (response, permanent deformation, SSI, floatation...) of the model with complex conditions such as shield/cut-and-cover tunnels, curves, complicated sections, traversing heterogeneous layers
- Compare results obtained from various centrifuge and shaking-table tests and numerical simulations with the E-Defense results as "benchmarks"
  - Evaluate influence of scales and other factors to improve the testing methods and simulations and to propose a testing guideline for design such as PBD

Proposed testing schedule for coming 4 years

- 2010: Feasibility study on E-Defense tests
  - Various centrifuge and shaking-table tests and numerical simulations to evaluate the feasibility and fix the specifications, and to obtain fundamental data from many types of tests and simulations
- 2011: E-Defense test of a non-liquefiable deposit
  - Pre- and post-simulations
- 2012: Evaluation of the test and plan of the next
  - Comparison of the other model testing and simulation results with the test
- 2013: E-Defense test of a liquefiable deposit
  - Pre- and post-simulations

Project (d) : Energy facilities - Study on the Safety Margin of Energy Facilities -

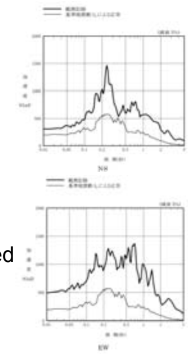
Izumi Nakamura

National Research Institute for Earth Science and Disaster Prevention

Project (d) : Energy Facilities

Background

- ✓ Components of energy plants need to remain in safety at seismic events.
  - ➢Not to cause the leakage of the high-energy fluid in these components.
  - ➢To keep the function of the facilities.
  - ➢The energy plants are expected to resume operations after the seismic events, provided the safety of the facilities are assured.
- ✓ Some earthquakes occur in Japan which exceed the seismic input level determined in seismic design.
- ✓The safety margin and structural integrity of the components is not clear which are struck by unexpected input motions.



Acc. response spectrum at KK-5 of TEPCO, at the Niigataken-chuetsuoki Earthquake in 2007

Project (d) : Energy Facilities

Objective

To clarify the seismic safety margins and structural integrity of components of energy facilities under large seismic motions, especially over the design level.

* Energy facilities :
Electrical generating facilities,
High-pressure gas facilities, etc.

* Components of energy facilities :
Piping systems, Supports, Containers, Tanks, etc.

In this study, main target is the components of energy plants.

✓ It is necessary to investigate the ultimate strength, failure modes, and the failure process until the components lost their function.

Project (d) : Energy Facilities

How to approach the tasks

- ✓ Shake table test (E-Defense Shake Table Test)
  - to clarify the seismic response and failure modes of components
- ✓ Non destructive inspection during the test
  - to detect the invisible damage before failure
- ✓ Numerical Analysis
  - to establish the numerical model to estimate the elastic-plastic response behavior and failure modes of the components

Clarify the seismic safety at and after the seismic events

Project (d) : Energy Facilities

Rough image of the test model at the first year (2010)

✓ Among the components of energy facilities, a piping system with some supports will be tested at the first year.

- ➢ Three dimensional shake table test on a piping system model.
  - ➢ Some containers or tanks may be included.
- ➢ Ultimate strength and failure modes will be obtained.
- ➢ Damage at the design level will be obtained.

Image of the shake table experiment

Project (d) : Energy Facilities

Additional problems

- ✓ Aging of the facilities
  - ➢ There are a lot of energy facilities constructed about 20 ~40 years ago.
  - ➢ Defects by aging effects, for example, wall thinning or cracks in the piping systems, will occur in such plants.
  - ➢ The effects of such defects on the seismic safety of components should be also investigated.

How to approach …

- Modify the defects in the component model.
- Conduct the shake table test.
- Compare the results of the models without defects.
- Clarify the feature of the failure of the degraded components and the effect of the defects on the seismic safety.

Project (d) : Energy Facilities

Future tasks

- ✓ Following items are not in scope of this study at present;
  - ➢ Seismic reliability of lifeline utilities and lifeline networks
  - ➢ Interaction of the soil foundation and the components

The research procedure itself should be well discussed when the shake table tests would be conducted.

Friday, The18th September, 16:00～17:30 Plenary Discussion on New Research Themes

E-Defense

Computational Simulation

***(Achievements of* E-Simulator : Virtual Shaking Table)**

Tatsuhiko Ine [1] , Koji Kajiwara [2]

1)Invited Research Fellow , 2)Senior Researcher

Hyogo Earthquake Engineering Research Center,

National Research Institute for Earth Science and Disaster Prevention (NIED, JAPAN)

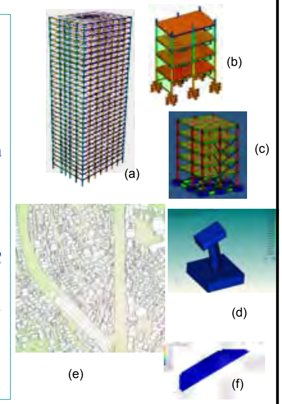
1

7th NEES/E-Defense Planning Meetings, September 18-19, 2009

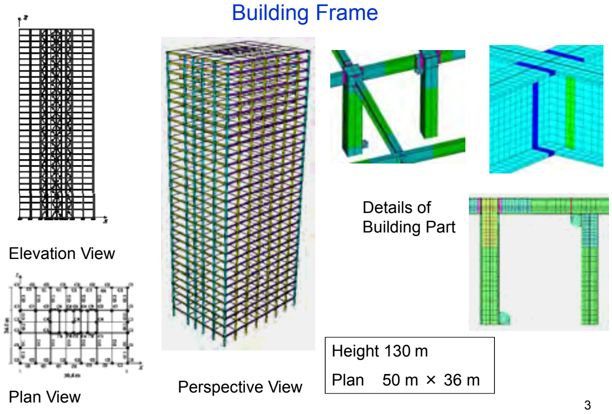
Project (e) : Computational Simulation

Achievements of E-Simulator : Virtual Shaking Table

- ・ADVENTURE Cluster：Adjusting Platform of E-Simulator (Commercial finite element package specially tuned for Parallel Computation)
- (a) FE Collapse Analysis of 31 Story Super High-rise Steel Building Frame
- (b) FE Analysis of the Collapse Experiment on 4-story Steel Moment Frame
- (c) FE Analysis of the Experiment on Passively-Controlled 5-story Steel Building with Dampers (Input Model Data)
- (d) PDS-FE Analysis of the Experiment on RC Bridge Pier
- (e) Integrated Earthquake Simulation of Urban Regions
- (f) FE Dynamic Collapse Analysis of Steel Building Components (Conventional Technique Improvements)



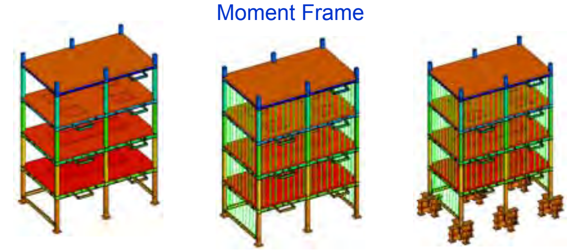
(a) FE Collapse Analysis of 31 Story Super High-rise Steel Building Frame



Height 130 m
Plan 50 m × 36 m

3

(b) FE Analysis of the Collapse Experiment on 4-story Steel Moment Frame



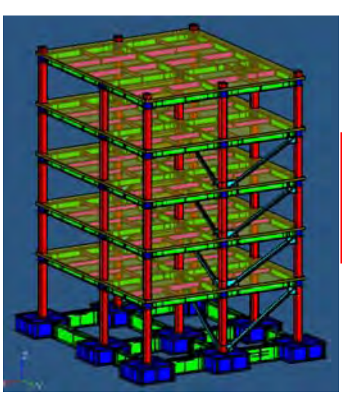
Height：14.375 m
Plan ：10m × 6m
weight：215 ton

Hexahedron Slid linear Element
Element 5,181,880, Node 7,523,295,
DOF 22,569,885

Case 2b ; Column Base

4

(c) FE Analysis of the Experiment on Passively-Controlled 5-story Steel Building with Dampers (Input Model Data)



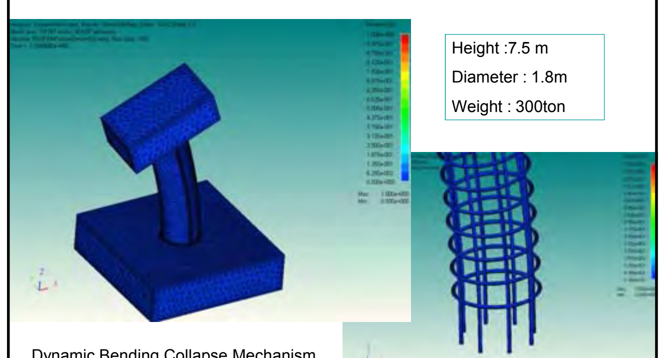
Height：18,555 m
Plan ：10m × 12m
Weight ：450 ton

Macro Command of Hyper-works (Pre-Processor)

Semi-Automatic Geometrical Feature FE Mesh Generation

5

(d) PDS-FE Analysis of the Experiment on RC Bridge Pier



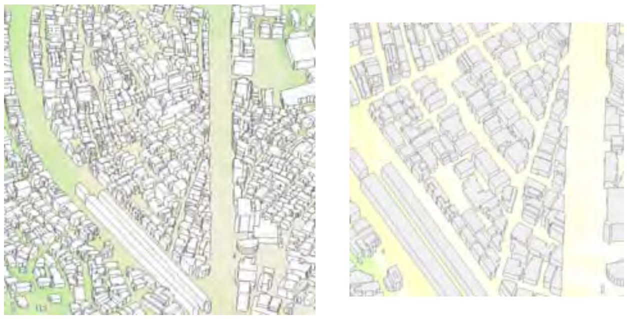
Height :7.5 m
Diameter : 1.8m
Weight : 300ton

Dynamic Bending Collapse Mechanism by Particle Discretization Scheme FEM

Deformation of Longitudinal Reinforcement

6

(e) Integrated Earthquake Simulation of Urban Regions

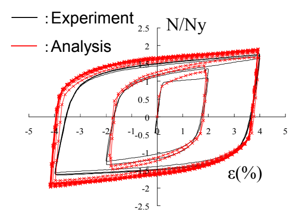


Nonlinear Dynamic Response Analyses
Urban Structures and Houses are shaken with large seismic motion.

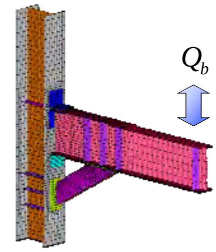
7

(f) FE Dynamic Collapse Analysis of Steel Building Components (Conventional Technique Improvements)

Knee-brace Damper FE Analysis with Nonlinear Combined Isotropic and Kinematic Strain Hardening Constitutive Equation



(a) Axial Force-Axial Strain Curves of Damper



(b) Finite Element Model

Alternative Cyclic loading of 12 Cycles (4 Nodes Quadrilateral Shell Element)

Future Works

- Ten years later, E-Simulator will be able to predict the dynamic collapse phenomena of various full-scale collapse experiments of E-Defense.
- The seismic hazard assessment of urban regions including the ground and social infrastructures will come true by the combination with E-Simulator and E-Defense.
- E-Simulator as Integrated Earthquake Simulator for urban regions will contribute the effective planning quakeproof countermeasures.

9

Thank you very much for your attention

10

E-Defense Data Archives —ASEBI— coming soon!

E-Defense
SAKAI Hisanobu
(saki@asroc.mydns.jp)

NIED

Concept

- SIMPLE and EASY
  - Easy Manageable
    - Based opensource CMS : ZOPE/Plone
    - Administrators are freed from the create security patches.
    - Security patches has been supplied from the community.
  - User Friendly
    - This web system can be operated intuitively.
  - Easy Scalable
    - The IsilonIQ System have adopted in backend file servers.
    - If you run out of storage, you buy the new box and connecting current system, the area will be extended within 30 seconds. There is no operations to reconstruct the area.

NIED

The DATA is only Contents

- All experimental data is in binary or ascii files.
  - Mesurement Data ➔ ASCII CSV File
  - Movie ➔ MPEG2 File
  - Report etc ➔ PDF or DOC
- Just only we want to access control them from everyone.

NIED

Screen shot 1(only Japanese)

NIED

Screen Shot2 (only Japanese)

NIED

Schedule

- ~Sep. 20
  The system has been reviewed by the some reviewer. (at Prototype)
- ~Sep. 25
  Based on the results of a review, making corrections.
  Uploading data for the system release.
  Apply the performance tuning.
- Sep. 28~
  System Release.

NIED

The End

- Working Team
  Supervisor : ABE Ken-ichi
  Leader : KAI Yoshihiro
  System Design : SAKAI Hisanobu (System)
  NAKAYAMA Manabu (Rules)
  Operator :SAKAGUCHI Tomoko
- Special Thanks
  Plone developers and users community (PLONE-jp) in Japan.

NIED

A Guideline for Breakout Sessions

A memorandum for the breakout sessions
The Second Joint Planning Meeting for Second Phase of NEES/E-Defense Collaborative Research on Earthquake Engineering
September 18 and 19, 2009, at E-Defense, Japan

Prepared by
Masayoshi Nakashima, E-Defense
September 11, 2009

Resolutions Adopted in First Planning Meeting

The following is the resolutions adopted in "the First Joint Planning Meeting for Second Phase of NEES/E-Defense Collaborative Research on Earthquake Engineering" held at the NSF Headquarters on January 11 to 12, 2009.

RESOLUTIONS

Based on the presentations, discussions and deliberations, the participants of the Planning Meeting for the second phase of NEES/E-Defense Collaboration formulated and unanimously adopted the following specific resolutions:

Resilient City as a Common Meta-Theme
The three meta-themes discussed in the meeting, i.e., "Disaster Resilient Communities", "Preparing for the Big One", and "Low-Probability, High-Consequence Events" are linked in many ways. The fundamentals of the first meta-theme are the damage reduction and quick recovery. These require developments of new materials and technologies that would enhance the performance of various components that form the urban area. Methods to detect the damage quickly and systems that can be repaired (or re-built) with minimal interruption of life and business are also the important topics to consider. In the second meta-theme, developments of new materials and technologies are the key to the prevention of a downward spiral of deterioration. The third meta-theme has much in common with the preceding two in light of the specific scientific challenges to be pursued. Thus, it was agreed that the 'Resilient City' provided a mutually important goal upon which members of the US and Japanese earthquake engineering communities could work and that US-Japan collaboration would accelerate realization of this goal and leverage the resources available in both countries.

Second phase of NEES/E-Defense Collaboration needed to speed realization of the Resilient City
Because of the importance of the Resilient City meta-theme to both the US and Japan, and the smooth and effective collaboration already established between NEES and E-Defense, the participants agree that a second phase of the NEES/E-Defense Collaborative Research Program in Earthquake Engineering is needed. They also endorse pursuing the 'Resilient City' meta-theme as the focus of the second phase. It is strongly believed that NEES/E-Defense collaboration by the US and Japan provides the strongest mechanism to accelerate the pace of discovery and development in engineering needed to realize the goals of the earthquake disaster resilient city.

Type of Collaboration
The Resilient City meta-theme requires an integrated effort of various disciplines (including architecture, economics, geotechnical and structural engineering, so on) and consideration of various types of engineered structures that make up a contemporary city (including buildings, transportation and other

lifeline systems). A strong tie between experimentation and computation is indispensable in these studies. For the implementation of this collaboration, it is recommended that joint "testbed" structures be introduced and that jointly funded capstone experiments be conducted. Such synergistic exercises serve as an important tool for integrating research findings accumulated from a variety of more specific sub-projects, explored by multiple small groups in both the United States and Japan, as well as for providing a final verification of the approaches, details and technologies developed. It is recommended to speed implementation and arrive at practical and cost effective solutions that engineering and other professionals are involved in the planning and interpretation of the research efforts.

Scientific Challenges and Specific Research Needs

In the scope of the meta-theme of Resilient City, scientific challenges and specific research needs as well as the benefit acquired through the NEES/E-Defense collaboration are shown below with respect to the focus area. Details of respective focuses are summarized in Appendix III.

Buildings. – The Resilient City, with undertones of low damage, quick recovery, and sensible rebuilding, needs new building materials, technologies and systems that efficiently control damage, as well as smart structures that can "tell you where it hurts." These high performance structures perform well whatever (within reason) is thrown at them, and sustain damage that can be quickly found and repaired. Attention should be focused on methods to improve the resilience of existing structures. Several concepts provide particularly attractive avenues to pursue through NEES/E-Defense collaborative research: Structures with clearly defined and replaceable fuses; self-centering systems (unbonded post-tensioned cast-in-place walls, seismic isolation (including use in high-rise structures), rocking/uplifting systems (including structure-foundation-soil interaction effects), new and innovative structural systems, etc.); Structures with improved nonstructural systems, including unibody systems that utilize nonstructural components as part of the lateral load resisting system; new high performance materials that are less susceptible to damage; super-resilient structures. Large-scale NEES and E-Defense tests of complete structural systems are important to provide essential "proof of concept" demonstrations as well as the quantitative data needed to calibrate design and analysis methods

Nonstructural Elements. – Damage to nonstructural components and contents contribute significantly to the safety of engineered structures during and following earthquakes and the cost and duration needed for repairs. Many nonstructural components are complex, often extending throughout a structure and interacting with other nonstructural systems (electricity, communications, etc.). The behavior of these systems is not adequately understood, and plentiful opportunities exist to develop improved nonstructural components that are more resistant to damage, or structural systems that substantially reduce damage to nonstructural components and systems. E-Defense and NEES tests provide many opportunities to improve our understanding of and ability to control the factors that govern the seismic performance of nonstructural elements and systems.

Transportation Systems. – Transportation systems are vital to the health, prosperity, and security of modern society. Recent earthquakes have shown these systems can be vulnerable to earthquake damage with unacceptable socio-economic consequences. Damage-free bridges with minimal loss of functionality and repair time should be explored, with cost effectiveness in mind, to facilitate post-earthquake emergency response and the rapid recovery of the effected region. Specific research needs include the development of damage-free smart bridges using innovative materials, devices, and configurations, the development of bridge configurations that enable faster repair, and the development of damage-free foundations subjected to large ground movement.

Lifelines, including geotechnical issues. – The focus of the research should be on buried lifelines and other underground structures. Damage to such buried structures during large earthquakes has serious implications for the life of a city as it may interrupt essential transportation, power and water supply functions, as well as trigger destructive fires following the earthquake. There are large and complex underground structures whose seismic performance and interaction with surrounding soils are not yet well understood. Engineering and scientific challenges are mainly in the areas of soil-structure interaction

(SSI) and geotechnical research. Specific research needs where E-Defense/NEES Collaboration would be most helpful were identified as follows: (i) response of subway stations, tunnels, and buried pipes; (ii) strategies to improve performance of underground structures; (iii) prevent flotation of underwater tunnels; (iv) development and evaluation of ground improvement and remediation strategies; (v) permanent ground deformation hazard and its effects, especially in challenging and heterogeneous soil profiles; and (vi) soil-structure interaction studies of both underground and above ground structures considering the whole structure-foundation-soil system. Tests at E-Defense should be generally planned as part of research programs including appropriate centrifuge and smaller shake table tests as well as a computational effort; in some cases coordination with testing at large static facilities like that at Cornell U. should also be considered.

Computational Simulation. – Numerical simulation of the full range of behavior of 3D structure-foundation-soil systems up through collapse is a basic tool needed to evaluate the seismic resistance and safety for a resilient city. Specific research areas include improvement of models of materials and components, particularly for non-ductile and deteriorating modes of behavior, development of algorithms and software systems that conform to modern computer architectures, simulation of collapse of 3D structural systems, and representation of the uncertainty in behavior. A true integration between experimentation and simulation modeling is needed to realize robust, high fidelity numerical simulation capabilities Hybrid tests and large scale shaking table tests are essential to carry out coordinated structure-foundation-soil interaction tests at a range of scales to improve the current simulation models and algorithms that use massively parallel computation.

Monitoring and condition assessment. – Structural health monitoring systems can provide vital information on the state of structure (a) before an earthquake leading to repair and strengthening, (b) during the emergency response period providing information on critically damaged or collapsed structures, and (c) during the recovery period information on the type and degree of damage of large number of structures reducing the recovery time. NEES and E-Defense tests provide important opportunities for conducting parallel structural health monitoring and prognosis projects that develop and implement structural health monitoring systems, and validate and calibrate damage diagnosis and prognosis algorithms. All these activities are needed to increase the resiliency of the earthquake-affected region.

Future Discussion and Establishment of Implementation Mechanism

The participants found that this meeting was an excellent starting point for jointly discussing critical societal level issues (meta-themes) that earthquake engineering should act upon to protect the welfare of contemporary society, and the contributions that NEES/E-Defense collaboration can make towards this end. Every effort has to be made, and any opportunity utilized, to continue and enhance the discussion between the two countries on this topic, and to put in place an implementation mechanism for the type of NEES/E-Defense collaboration discussed. Several opportunities exist in the near-term to continue these discussions. These include a full-scale test at E-Defense in early March 2009 on a steel structure equipped with various passive dampers; the 2009 NEES annual meeting in Hawaii in mid-June 2009; and another full-scale test at E-Defense in August 2009 on a NEES rocking frame.

The participants also agreed that the Joint Technical Coordinating Committee (JTCC) of NEES/E-Defense collaboration should be reorganized so that the committee can take a more active role to the planning of the collaboration in addition to its implementation. This is a subject for resolution as quickly as possible.

Considered Projects at E-Defense

Currently, the following four projects (a) to (d) have been considered at E-Defense.

(a) New materials and new technologies
(b) Base-isolation and vibration control
(c) Geotechnical engineering
(d) Energy facilities

Although we do not officially use the name of "Resilient City", the spirit described in the resolutions has been embedded in these projects.

In the resolutions, "buildings", "nonstructural elements", "transportations", "lifelines and geotechnical engineering" have been identified as specific research needs. Project (a) deals with building structures in which new materials, new elements, and new systems are incorporated. The project is in commensurate with the needs associated with "buildings." The project naturally includes "nonstructural elements". As easily understood, "nonstructural elements" are the best candidate for payload tests. Project (b) aims at next generation base-isolation and structural control. Issues discussed in "buildings" and "transportations" are in line with this project. Project (c) deals with soil and underground lifelines/structures. The project naturally cover various aspects discussed in "transportations" and "lifelines and geotechnical engineering". Project (d) focuses on energy facilities, which is closely associated with "lifelines".

The following two themes were also discussed in the resolutions. These are naturally considered in the planned projects. In fact, each project shall include these aspects, and "monitoring" suits to payload tests.

(e) Computational simulation
(f) Monitoring

Planned Contents and Time Frame of Projects

Considering the mission and nature of the E-Defense facilities, each project has to implement large-scale shaking table tests. At present, two large tests are planned for each year, and the time table being considered is as shown below. (Note that the Japanese fiscal year begins on April 1.)

	Fiscal 2010	Fiscal 2011	Fiscal 2012	Fiscal 2013
Project (a)	X X			
Project (b)	X X			
Project (c)	X X			
Project (d)	X X			

Suggestions for Breakout Sessions

According to the tentative agenda, E-Defense presents the outlines of the four projects on the afternoon of Day 1. In addition, E-Defense also plans to introduce its current activities on computational simulation and data repository system.

During the breakout sessions scheduled in Day 2, E-Defense wishes to learn the US interests in the projects being considered by E-Defense and welcomes comments and suggestions on the pursuit of the projects. E-Defense also wants to know the research projects that the US researchers have in mind and discuss how E-Defense can collaborate with potential US projects.

Finally, expected in the meeting is:

- Better mutual understanding about the Second Phase NEES/E-Defense Collaboration
- Identification of specific subjects that both parties can collaborate on
- Discussion on efficient mechanism of collaboration

Three breakout sessions are being considered in the tentative agenda, i.e., (a) New materials and new technologies, (b) Base-isolation and vibration control, and (c) Geotechnical engineering. If we can recruit a sufficient number of researchers, (d) Energy facilities may also be set up as another breakout session. Those interested in (e) Computational simulation and (f) Monitoring are kindly asked to join one of (a) to (c) (or (d)).

Besides (a) to (f), E-Defense has been working on (g) Data repository system for the past years and is glad to announce that the developed system is ready for general service. Dependent on the US interest, we may set up another short breakout session for (g).

<END>

Breakout Session1 (September 19, 2009)

Themes	Suggested Participants
New materials and new technologies	Moderator: Hitoshi Shiohara (Univ. of Tokyo) Jack Moehle (UC Berkeley) Recorder: Ken Elwood (Univ. of British Columbia)
	<USA> James Wight (Univ. of Michigan) Wassim Ghannoum (Univ. of Texas, Austin) Gustavo Parra-Montesinos (Univ. of Michigan) Laura Lowes (Univ. of Washington) Richard Sause (Lehigh Univ.) John Wallace (UCLA) Manos Maragakis (Univ.of Nevada, Reno) Julio Rameriz (Purdue Univ.) <Japan> Toshimi Kabeyasawa (ERI, Univ. of Tokyo) Susumu Kono (Kyoto Univ.) Taizo Matsumori (E-Defense, NIED) Takuya Nagae (E-Defense, NIED) Tatsuhiko Ine (E-Defense, NIED) Matsutaro Seki (E-Defense, NIED)
Base-isolation & vibration control	Moderator: Satoshi Fujita (Tokyo Denki University) Keri Ryan (Utah State Univ.) Shirley Dyke (Washington Univ.) Recorder: Gilberto Mosqueda (Buffalo) Troy Morgan (Tokyo Institute of Technology)
	<USA> Reggie DesRoches (Georgia Tech) James Ricles (Lehigh Univ.) Narutoshi Nakata (John Hopkins) Andreas Schellenberg (UC Berkeley) Steve Mahin (UC Berkeley) Charles Roeder (Univ. of Washington) Andrei Reinhorn (SUNY Buffalo) Bozidar Stojadinovic (UC Berkeley) <Japan> Kazuhiko Kasai (Tokyo Institute of Technology) Akira Nishitani (Waseda Univ.) Kazuhiko Kawashima (Tokyo Institute of Technology) Yoshikazu Takahashi (Kyoto Univ.) Yoshiki Ikeda (Kajima) Eiji Sato (E-Defense, NIED) Kouich Kajiwara (E-Defense, NIED) Tsuyosi Hikino (E-Defense, NIED) Yoshiro Kai (E-Defense, NIED) Matsutaro Seki(E-Defense, NIED)
Geotechnical engineering	Moderator: Ikuo Towhata (Univ. of Tokyo) Ahmed Elgamal (UC San Diego) Recorder: Adda Athanasopoulos-Zekkos (Univ. of Michigan)
	<USA>

	Scott Ashford (Oregon State University) Steve McCabe (NEESinc) <Japan> Kohji Tokimatsu(Tokyo Institute of Technology) Muneo Hori (ERI, Univ. of Tokyo) Knetaro Tabata (E-Defense, NIED) Izumi Nakamura (E-Defense, NIED) Takahito Inoue (E-Defense, NIED)
Breakout Sessions2	
Energy facilities	Moderator: Izumi Nakamura (E-Defense, NIED) Andrei Reinhorn (SUNY Buffalo) Recorder Bozidar Stojadinovic (UC Berkeley)
	<USA> <Japan> Masayoshi Nakashima(NIED)
Numerical simulation&IT	Moderator: Muneo Hori (ERI, Univ.of Tokyo) Gregory Deierlein (Stanford University) Recorder Andrea s Schellenberg (UC Berkeley)
	<USA> Solomon Yim (Oregon State University) Rudolf Eigenmann(Purdue) Ahmed Elgamal (UC San Diego) Bozidar Stojadinovic(UCB) Scott Ashford (Oregon State University) Wassim Michalel Ghannoum(Univ.of Texas) Adda Athanasopoulos-Zekkos (Univ. of Michigan) Andrei Reinhorn (SUNY Buffalo) <Japan> Yoshikazu Takahashi (Kyoto Univ.) Kazuhiko Kasai (Tokyo Institute of Technology) Tatsuhiko Ine (E-Defense, NIED) Yoshiro Kai (E-Defense, NIED) Matsutaro Seki(E-Defense, NIED)
Monitoring	Moderator: Akira Nishitani (Waseda Univ.) Shirley Dyke (Washington Univ.) Recoeder Narutoshi Nakata (John Hopkins)
	<USA> Julio Rameriz (Purdue Univ.) <Japan> Yoshiki Ikeda (Kajima) Tsuyosi Hikino (E-Defense, NIED)

Here is a message from E-Defense. We would like to add a few words about the scope of breakout sessions as shown below.

(1) In this meeting, the Japanese projects being proposed to MEXT are scheduled to be introduced on the afternoon of Day 1 (September 18, 2009). The proposals are very much commensurate with the discussions and proposals discussed in the Washington DC meeting last January. Although becoming late, we would like to send you separately the draft ppts that describe the outline of the proposals.

(2) With these proposals as a starter, we would like to have open, in-depth discussion about what we can do together within the scope of NEES/E-Defense collaboration. As the Japanese proposals are introduced in Day 1, we would like to use most of Day 2 to receive the US comments about

the Japanese proposals and more importantly to listen to the US research perspectives and proposals relevant to the concerned subject areas. Along this line, we wish to change the titles of the Day 2 program slightly as shown in blue of the latest Agenda draft.

(3) Although the time is limited and also the number of possible attendees in each breakout session (see the table below) varies rather significantly, we would like the US participants to prepare for discussions related to the US research perspectives and proposals.

(4) To assist your preparation for the discussion, here is the time frame; a total of four hours, consisting of one hour and fifteen minutes in the morning and two hours and fifteen minutes in the afternoon, plus half an hour to prepare for the summaries, has been reserved for the Day 2 (September 19) discussion.

Session Summary Report
Project (a) New Materials and Technologies

Moderators: Jack Moehle and Hitoshi Shiohara
Recorders: Ken Elwood
Members: John Wallace, Jim Wight, Wassim Ghannoum, Laura Lowes, Richard Sause, Gustavo Parra-Montesinos, Solomon Yim; Japan – Toshimi Kabeyasawa, Susumu Kono, Taizo Matsumori, Takuya Nagae, Tatsuhiko Ine, Matsutaro Seki

Specific Research Needs:

As we move toward disaster resilient communities, there is a need for research in the following areas:

- Development of new high-performance structural systems able to withstand significant ground shaking with limited damage.
- Demonstration of the seismic performance of existing design procedures for reinforced concrete buildings to determine how much damage is expected during strong ground shaking.
- Demonstration of how new structural systems, potentially incorporating new high-performance materials, can be used to achieve better performance at lower costs.

Shaking table tests are planned at E-Defence for 2010 and 2012. For 2010, it is proposed to test simultaneously two four-story buildings, one of conventional construction while the other represents a new innovative form of construction (see conceptual designs shown below). The following configuration is envisioned:

  - 75-80% scale
  - Wall on each transverse end (fixed base for conventional, rocking wall for new system)
  - Frames in longitudinal direction (post-tensioned frame for new system)
  - Transverse dimension: 1 bay @ 6.5m
  - Long direction: 3 bays @ 4.8m
  - 27 MPa concrete
  - Floor slab: monolithic but allow for breathing of post-tensioned frame (15cm thick)
  - Capacity roughly same for both systems
  - Ratio of strengths in two directions: 4/3

Project members will work closely to define scope and focus of 2012 shake table tests. It is currently envisioned that this test will investigate the seismic performance of tall reinforced concrete buildings to be built in the future in Japan and US.

Desired Collaborations and Benefits of collaboration:

Many forms of collaboration are envisioned, including:

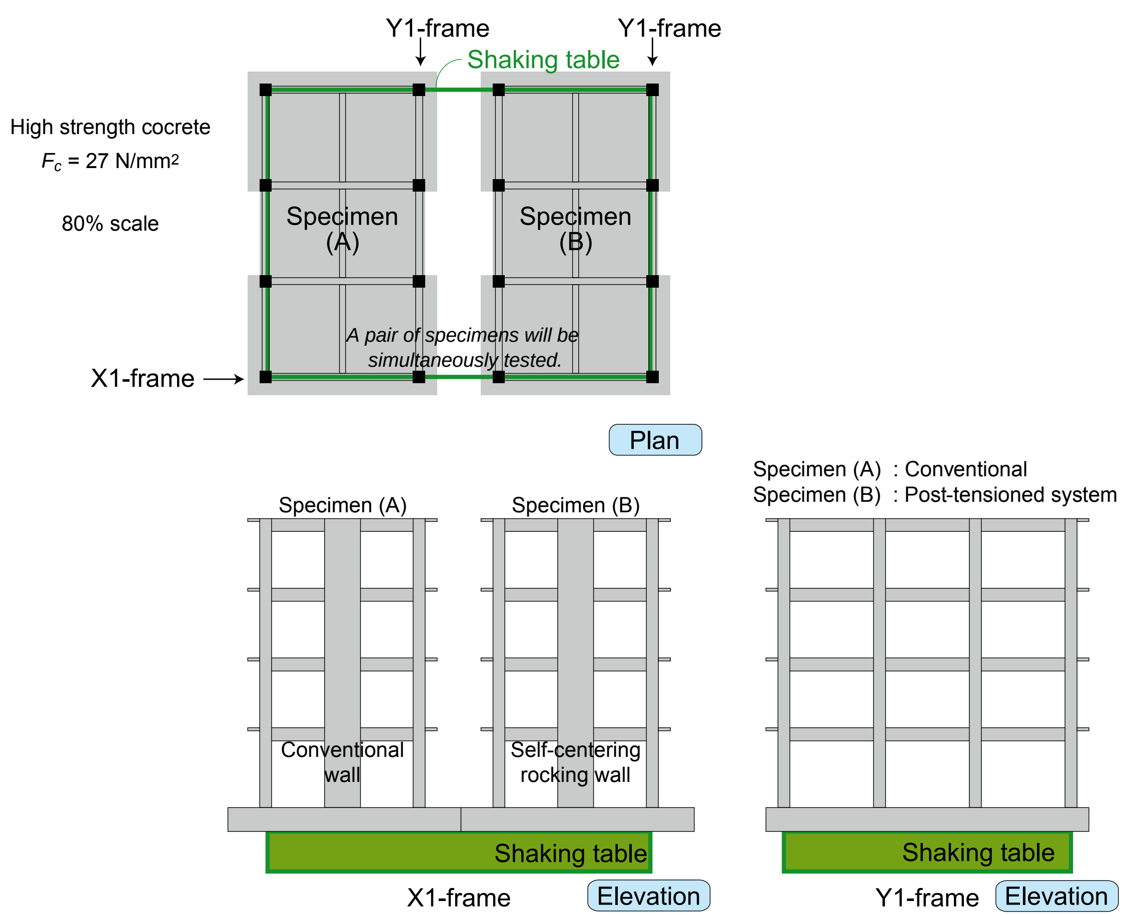
- Use of testbed structures (example buildings) to ensure close interaction of all participants.
- Design of shake table test specimens that reflect structural design practice, now and in the future, in Japan and US.

- US side will participate in the design of specimens and plan component tests for NEES facilities.
- Exchange of personnel (graduate students and faculty members) during design, construction and testing of specimens.
- Exchange of data from shake table and component tests.

To facilitate this collaboration frequent meetings are planned during the design phase for 2010 specimens. Face-to-face meetings are currently planned for October in San Francisco and February in Japan. Web meetings will be planned at regular intervals between these key face-to-face meetings.

Some important benefits of collaboration include:

- Exchange of ideas leading to improved design procedures for innovative systems in Japan and US.
- Maximize benefits of testing facilities in Japan and US.
- Exchange of graduate students will broaden the educational experience for Japanese and US students and will lead to the development of international contacts for future research collaboration.
- Maintain a strong history of collaboration in earthquake engineering research between US and Japan.



Conceptual plan for structural framing as developed during the workshop.

Session Summary Report
Project (b) Base Isolation and Vibration Control

Moderators: Keri Ryan, Shirley Dyke and Satoshi Fujita
Recorders: Troy Morgan and Gilberto Mosqueda
Participants: JAPAN – Kazuhiko Kasai, Akira Nishitani, Yoshikazu Takahashi, Yoshiki Ikeda, Eiji Sato, Kouich Kajiwarea, Tsuyosi Hikino, Yoshiro Kai; US - Reggie DesRoche, James Ricles, Narutoshi Nakata, Andreas Shellenberg, Steve Mahin, Charles Roeder, Andrei Reinhorn, Boza Stojadinovic, Greg Deierlein.

Specific Research Needs:
The resolution adopted for the second phase of the NEES/E-Defense Collaborative focuses on the 'Resilient City' as a meta-theme. Based on the number of participants and discussions held during the breakout session, there is strong interest from both the Japan and US side to address the challenges of the Resilient City through *Project (b) Base Isolation and Vibration Control*. A key objective of the discussed research plan is to demonstrate, through full-scale component and system level simulations, the reduced vulnerability of buildings and infrastructure with protective systems. The proposed research will provide the data and tools to quantify the improvement in resilience of structures with base isolation and vibration control, leading to wider acceptance and use of advanced technologies for earthquake protection of important urban facilities. The specific research needs in this area were identified and categorized within three main subthemes. Note that the subthemes are similar to those previously identified by the E-Defense Researchers.

Innovative Isolation Systems - Active, Semi-Active, or Hybrid Seismic Isolation with TMD or AMD
Much effort has been devoted to develop and test at small scale active and semi-active earthquake protection devices that may provide improved performance over existing passive devices. In particular, the seismic performance of buildings with a combination of different types of passive semi-active or active devices has not been verified experimentally at large scale. The potential advantages to these systems are in the ability to adapt to the particular seismic demands and remain effective in protecting a structure under various types and levels of excitation. Examples of the innovative systems include (1) hybrid isolation with passive isolators at the base and additional tuned or active mass dampers within the superstructure to further mitigate vibrations, (2) actuators and/or controllable dampers installed within a seismically isolated structure, and (3) adaptive sliding isolation systems designed to optimize the seismic response in both low and high levels of excitation. Breakout session participants identified the need to test new devices or combination of devices, developed both in Japan and the U.S., at full-scale on an earthquake simulator.

Seismic Isolation and Control for Long Period Earthquakes
There has been a deep concern, particularly in Japan, on the potential effects of subduction type earthquakes that produce long-period long-duration shaking that may be detrimental to flexible buildings such as tall buildings and seismically isolated buildings. Breakout participants identified the need to develop improved testing or substructuring methods to simulate the response of tall buildings, both with and without seismic isolation. Verification tests of seismic isolation in combination with tall or flexible superstructures are also needed. Long period or

large magnitude ground motions that exceed the design earthquake will drive seismic isolation systems and other protective systems beyond their design limits. Thus, breakout participants agreed that ultimate performance limit states of passive/active seismically isolated buildings and critical facilities (e.g. nuclear power plants) should be evaluated. Comparison of limit states may identify the preferred method to safeguard against collapse in the event that seismic demands in an earthquake greatly exceed the design demands. The types of failures or events that can occur under extreme shaking include:

- Engaging large displacement stiffening of devices
- Pounding against moat wall
- Buckling and stability of devices
- Deformation limits of damping devices
- Consequences of superstructure yielding

Next Generation 3D Seismic Isolation

Both Japan and U.S. participants expressed strong interest to develop vertical isolation systems, particularly for nuclear power plants. Devices capable of achieving 3-D isolation have been proposed in both countries and testing is needed to validate these devices.

Desired Collaborations and Benefits of Collaboration:

Base isolation and vibration control strategies can address the challenges of the resilient city by reducing the vulnerability of buildings and infrastructure to earthquake shaking. Participants proposed the development of a test-bed structure that can be used for full-scale verification of the performance of different control devices and systems from both Japan and the U.S.. A test-bed serves two potential benefits; first, the performance of innovative protective systems can be benchmarked against each other and against conventional seismic isolation or fixed based solutions. Second, design procedures for protective systems, which are distinctly different in the U.S. and Japan can be comparatively evaluated. Participants proposed that the test bed can consist of a reusable steel or concrete frame structure suitable for 3-D loading. Alternatively, the existing E-Defense test bed structure can be modified to allow for installation of protective systems with frames representative of many types of structural systems, but this may limit applications to loading in one direction. Breakout participants also emphasized the need to develop damage detection and health monitoring systems for these devices.

There are many clear benefits to this collaboration, including the combined benefit of E-Defense and NEES experimental facilities for full-scale verification of protective systems for buildings. The collaboration can lead to improved acceptance of new technologies based on full-scale tests with benchmark data to compare different design methodologies and procedures. Researchers from Japan and U.S. will also engage in the exchange of technologies and adaptation of these technologies for implementation in other countries. Further, the international collaboration will expose researchers and students to engineering research and education from a global perspective and prepare them to be competitive leaders in a global economy. The combined knowledge and experience on both sides will provide

- Joint development of simulation capabilities for highly nonlinear behavior of isolation systems and structures,
- Development of benchmark structures (building, bridge, etc.) to evaluate different devices

- Develop an online environment for exchange of ideas (eg. NEEShub with automatic translator)

Session Summary Report
Project (c) Geotechnical and Lifeline Engineering

Moderators: Ikuo Towhata (University of Tokyo)
Recorders: Kentaro Tabata (NIED)
Adda Athanaspoulos Zekkos (University of Michigan), Ahmed Elgamal (University of California, San Diego), Scott Ashford (Oregon State University), Steve McCabe (NEESinc), Joy Pauschke (NSF), Kohji Tokimatsu (Tokyo Institute of Technology), Muneo Hori (University of Tokyo), Izumi Nakamura (NIED), Takahito Inoue (NIED), Kentaro Tabata (NIED)

Specific Research Needs:

Recently many mega cities are developing underground lifelines. Since many of mega cities are situated in seismically active regions, it is essentially important to improve the seismic resistance and resiliency from the viewpoints of people's safety and easier recovery from the earthquake effects.

The present project is going to concern big lifelines such as subway tunnels and stations. There are many examples of complex tunnels and stations where many railway lines, horizontal connections, and vertical shafts are connected with one another. Although studies on soil-structure interaction during earthquake shaking have been studied, still much is not known yet about that in a complex configuration of tunnels as well as geological boundaries. Therefore, the present study is going to investigate details of soil-structure interaction through large-scale model tests by using a realistically complex tunnel models. It is expected that the present study will improve our understanding of soil-structure interaction, make it possible to evaluate the present safety level of subways, and develop any retrofitting technology. Thus, its contribution to people's safety will be remarkable.

In addition, because the U.S. and Japan are the highly advanced countries with potential to develop technologies and designs to mitigate earthquake disasters, our challenging research collaboration can play the leadership role in terms of geotechnical earthquake engineering disciplines in the world. Such collaborative action leads to establish global de-facto standards in this frontier of geotechnical earthquake engineering for mega cities..

Based on the above backgrounds and motivations, the following research subjects are needed:

1. Improve safety of urban transportation systems and underground structures under earthquake loading
2. Improve resilience of lifelines
3. Develop better understanding of SSI effects in lifelines including:
    a) geologic boundaries
    b) lifeline cross-sections and 3-D geometric configurations
    c) effect of large soil deformations, such as surface depressions and lateral spreading
    d) effects of soil liquefaction including uplift and lateral earth pressure
4. Validate numerical models for dynamic response of tunnels and large pipes
5. Development and assessment of resilient mitigation measures
6. Use modern latest technology to improve people's safety during earthquakes

Desired Collaborations and Benefits of Collaboration:

1. Complimentary combination of large soil and SSI tests at E-Defense with smaller 1g shaking table and 2-D centrifuge tests at NEES facilities
2. Complimentary cooperative computational simulations
3. Calibration of numerical techniques based on large scale experimental results
4. Development of guidelines, assessment tools and practical recommendations based on the E-Defense and NEES data sets
5. Faster dissemination of results at the international level
6. Promotion of interdisciplinary structural-geotechnical experimental/numerical research approach
7. International collaboration to develop younger generation of geotechnical engineers

Session Summary Report
Project (d) Energy Facilities

Moderators: Izumi Nakamura (NIED) and Bozidar Stojadinovic (University of California Berkeley)
Recorders: Bozidar Stojadinovic
Members: Andrei Renhorn (University at Buffalo), Masayoshi Nakashima (NIED, E-Defense), Stephen Mahin (University of California Berkeley), Steve McCabe (NEESinc), Joy Pauschke (NSF), Jack Hayes (NEHPR/NIST)

Specific Research Needs

Modern way of life in both Japan and the US depends on an uninterrupted supply of electric energy. Electricity permeates not only industry, transportation and communications, but also conduct of business, education and social functions in our societies. Insuring uninterrupted production and supply of electricity is, therefore, a task of utmost importance for the structural engineers in Japan and in the US. The electricity production facilities and the electricity distribution grids in our countries are exposed to two hazards: 1) long-term deterioration; and 2) earthquakes.

The E-Defense-NEES meeting focused on the seismic hazard exposure of electricity transmission and production facilities. It was agreed that we share a common performance objective for such facilities: insure a high confidence in high probability of immediate operation of electricity production and transmission facilities under the rare earthquake hazard. Therefore, a common research objective was identified by both sides: to clarify the seismic safety margins of components of energy facilities and investigate the facility structural integrity and ability to operate under earthquake ground motions larger than the design basis level considered for the particular facility.

Both sides also recognized that the energy facility components present just a special case of the general class of high-importance infrastructure facilities. These include natural gas energy generation facilities, liquid natural gas storage facilities, petrochemical refining, storage and transportation facilities, and water purification, transportation and storage facilities. Formulation of a meta-facility, characterized by complex interaction of components, systems and structures, need for multi-physics modeling and simulation capabilities to characterize seismic fragilities, and opportunity to effectively utilize a wide range of seismic response modification methods to reduce the seismic risk of such facilities, was suggested. The final outcome of the collaborative E-Defense-NEES research should be the development and validation of design ideas for the next generation of infrastructure facilities. The following specific research tasks were identified:

1. Characterize the beyond design basis seismic hazard exposure of typical electrical power generation facilities in Japan and in the US.
2. Select electrical power generation equipment components typical for Japanese and US facilities and identify commonalities among them.
3. Conduct shaking table tests to examine the seismic performance and indentify failure modes of the tested components.

4. Conduct non-destructive tests to detect progression of damage before failure.
5. Develop and use the test data to validate numerical models capable of reproducing the identified damage states from initiation to failure.
6. Investigate the feasibility and quantify the benefits of using response modification devices to significantly increase the seismic margin of electric power facility components, systems and structures.
7. Develop and validate probabilistic performance-based methods to compute fragilities of the electric power production facility components and systems
8. Disseminate the obtained fragility data and introduce it into design code documents in Japan and in the US.

Desired Collaborations and Benefits of collaboration:

A very strong conclusion was formed that collaborative experimental research is needed to facilitate a comprehensive fragility evaluation of the wide variety of electric power facility components and systems. Both sides will greatly benefit from a coordinate research approach in this area of vital importance. The following collaboration opportunities were identified:

1. Integrate equipment qualification test data from tests already conducted on in the US and Japan with the newly conducted beyond-design-basis tests planned at E-Defense.
2. Conduct complementary large-scale tests using E-Defense for large and US shaking tables for comparatively smaller equipment. Use US shaking tables to conduct tests under differential support motions.
3. Conduct complementary and cooperative computational simulations to calibrate the numerical models using large-scale test data on the response of components, systems and structures.
4. Integrate response modification devices into the design of electric power facilities.
5. Develop fragility data with the common performance basis.
6. Develop design guidelines, assessment tools and practical recommendations based on the E-Defense and NEES data sets.
7. Enable fast dissemination of results at an international level and promote international collaboration in the field of critical infrastructure.
8. Develop younger generations of structural engineers specializing in critical infrastructure facilities.

Session Summary Report
Project (e) Monitoring

Moderators: . Akira Nishitan (Waseda University) and S. Dyke (Purdue University)
Recorders: Narutoshi Nakata (Johns Hopkins University)
Members: Y. Ikeda (Kajima Corp.), T. Inoue, and T. Hikino

Specific Research Needs

Structural monitoring seeks to capture changes in structural properties and conditions due to long-term deterioration as well as extreme events such as earthquakes and strong winds. Estimated properties and observations play a critical role in detection of damage, assessment of structural design, estimation of remaining life-cycle, etc. However, such tasks are still challenging for built structures, particularly for large and complex structural systems. Further research on structural monitoring is needed to improve maintenance and rehabilitation measures of civil structures.

While significant technological advancements have been made in recent years, including sensing devices, algorithms, etc., applications of structural monitoring are still limited: current monitoring programs are mainly for research, and acquired data has not been used for practical purposes such as decision making in structural maintenance. Remaining obstacles are gaps that currently exist between research and practice. More research on structural monitoring need to be directed toward practical applications.

The breakout session for monitoring during the E-Defense/NEES meeting discussed the research needs and community-wise coordinated efforts required to advance monitoring technologies for civil structures. Identified subjects are following:

1. Improve methods to detect changes in structures
2. Develop sensor fusion strategies
3. Assess type and density of sensors required to meet monitoring objectives
4. Validate algorithms for detecting structural changes through full-scale testing or monitoring
5. Learn from data and resources that are available in the community
6. Develop quantitative means to transfer structural monitoring technology
7. Educate practicing engineer and future generation on the capabilities and challenges of structural monitoring

Desired Collaborations and Benefits of collaboration:

1. Identification of objectives of monitoring in US and Japan
2. Compilation of state-of-the-art structural monitoring technologies
3. Benchmark study using full-scale experiments at E-Defense and NEES facilities.
4. Data sharing to help development of monitoring technologies and algorithms
5. Dissemination of capabilities of monitoring to practicing engineering communities

Session Summary Report
Project (f) Simulation

Moderators: Muneo Hori (University of Tokyo) and Greg Deierlein (Stanford University)
Recorders: Andreas Schellenberg (UC Berkeley), Tatsuhiko Ine (E-Defense)
Members: Rudolf Eigenmann (Purdue), Shirley Dyke (Purdue), Boza Stojadinovic (UC Berkeley), Keri Ryan (Utah State Univ.), Tsuyosi Hikino (NIED,E-Defense), Yoshikazu Takahashi (Kyoto Univ.), Solomon Yim (Oregon State), Gilberto Mosqueda (SUNY)

Background

As described in discussion paper[1] from the NEES/E-Defense Phase 2 planning meeting held at the U.S. NSF in January 2009, computational research in earthquake engineering is generally not making full use of unprecedented computing capabilities of modern multi-processor supercomputers that are supported by massive data storage and networking capabilities. This is in contrast to the situation during the early US-Japan cooperative earthquake engineering programs of the 1970's, when computational research in earthquake engineering was at the forefront of computational methods. Particularly in light of the major investments in the NEES and E-Defense facilities that offer unprecedented capabilities for physical testing of large-scale structures, there is an important need for commensurate research to advance computational methods in earthquake engineering.

During the NEES/E-Defense Research Coordination meeting, there were several presentations that illustrated the challenges posed to develop models to simulate the complex nonlinear dynamic behavior of structures subjected to earthquake effects. For example, Professor Kawashima (Tokyo Institute of Technology) described the complexities of size effects and loading histories on the axial load, shear and bending behavior of large reinforced concrete columns; and Professor Kasai (Tokyo Institute of Technology) described the collapse behavior of a full-scale steel framed building. These illustrate the complex phenomena that can currently only be accurately evaluated by physical tests. Future research plans at E-Defense anticipate testing of high performance RC, systems with isolation and passive/semi-active control, buried structures, and utility lifeline facilities – all of which involve similarly complex behavior.

Recognizing the opportunity afforded by modern computational technologies, NIED and E-Defense are embarking on a major initiative to develop computational technologies of unprecedented size and resolution with capabilities to support models with millions of elements and tens of millions of degrees of freedom. They are using the Adventure Cluster (ADVC) software platform, which provides fast solvers that are highly scalable to run on super computer clusters. ADVC is a large freeware computational code that is well-suited to support scholarly research. A platform called AVS is used for data visualization. To date, the capabilities have been demonstrated with nonlinear dynamic analyses of a bridge specimen that was tested at E-Defense, a 31-story steel building, and a model of a large distributed urban region that employs both structural and geotechnical components. While unprecedented in size (number of elements

[1] Hori, M., Fenves, G.L., "White Paper on Computational Simulation", *Report of the First Joint Planning Meeting for the Second Phase of NEES/E-Defense Collaborative Research on Earthquake Engineering*, PEER 2009/101

and degrees of freedom), the analysis models employ fairly conventional element meshes and basic plasticity-based material models. Future plans are to make the models more realistic with better constitutive material models for steel, concrete, and soils – including discrete particle implementations to simulate cracking in concrete.

Specific Research Needs

Earthquake engineering research and design are dependent on our ability to simulate numerically the full range of seismic behavior exhibited by engineered systems, from low-level vibrations through to those initiating collapse. Robust and reliable computational tools are essential to understand the fundamental mechanisms that control behavior, as well as to have adequate assurance in the safety and performance of existing and new structures. Many challenges remain for us to be able to predict realistically the ultimate behavior of structures. The E-Defense computational initiative envisions capabilities to accurately simulate failure modes and large deformation (collapse) response of the buildings, bridges and other infrastructure using fundamental models of nonlinear material behavior. The goal is to simulate complex nonlinear behavior, such as may be observed in the following types of components and systems:

- Nonlinear failure modes due to combined axial load, shear and bending in large RC bridge piers and walls under random dynamic loading.
- Steel buildings that exhibit collapse due to large deformations combined with fracture and local buckling.
- Ultimate limit state behavior of seismically isolated systems when the ground motion demands exceed the design displacement of the isolators.
- Behavior of underground structures (tunnels, pipes, basements) subjected to the combined effects of ground shaking and deformations.
- Collapse of structures subjected to ground shaking combined with tsunami wave run up.

To address these challenges, we need to:

1. Develop tools and services that harness the potential offered by petascale-computing environments so that we are able to more realistically simulate facilities and regions subjected to earthquakes,
2. Compare and validate results predicted by computational models with those from physical experiments, ranging from material, component, sub-assemblage, shaking table and field tests,
3. Engage in cooperative planning of complimentary computational and physical experiments, and
4. Develop and maintain data, information and visualization models, technologies and network services to support these computational simulation efforts.

Specific research needs having high near-term priority include:

1. Extending, validating, deploying and maintaining high performance simulation platforms such as ADVC, OpenSees, and so on.
2. Carryout challenging testbed applications to evaluate and improve where necessary simulation tools. Candidates for testbeds include: structural systems constructed from

reinforced concrete, steel and other materials, soil and soil/structure interaction problems, and fluid and fluid/structure interaction problems.

3. Active development and validation of constitutive and damage models to improve simulation under complex stress states and loading conditions.
4. Improvement of computational solution and numerical integration techniques, to simulate large structures more efficiently, and to achieve more robust solutions for highly nonlinear systems exhibiting degrading behavior, etc.
5. Development of improved data and information models to facilitate conducting, managing, visualizing and calibrating/validating computational and physical simulations.
6. Improvements in hybrid simulation using high performance simulation and information technology including the linking of advanced physical/computational models with high performance simulation platforms.
7. Conduct validation case studies, including consideration of the effects of uncertainties. These studies should include experiments conducted on sub-assemblages, shaking tables (NEES and E-Defense) and in the field (NEES facilities at UC Santa Barbara, UCLA, and the University of Texas).

Desired Collaborations and Benefits of collaboration:

Collaboration is desired at several levels.

a. Direct collaboration between NEEScomm (OpenSees, NEEShub, etc.) and E-Defense (ADVC) groups developing, deploying and maintaining high performance computational simulation capabilities and information exchange and database systems is desirable to leverage resources and knowledge and to promote sharing of critical information and technologies.
b. It is believed that advanced computational simulation should be an integral part of all NEES/E-Defense projects, and that payload and other efforts to apply specialized computational simulation tools and models to these projects should be encouraged.

To support this collaboration, it is desired, in addition to regular NEES/E-Defense planning meetings, to establish a website to facilitate communication and collaboration.

A benefit of an energetic research program on simulation as outlined above would be improved understanding of the characteristics of structures and ground motions that control seismic response, improved confidence in our ability to predict the highly nonlinear, dynamic response of complex structures to future earthquakes, and a computational foundation upon which to build more reliable design guidelines to improve the safety, economy and performance of structures.

It is believed that substantial interest exists in Japan and the US related to high performance simulation and that opportunities exist to write and submit proposals to NSF and MEXT that would leverage the limited funding currently available within the NEES/E-Defense framework. This would substantially accelerate progress towards the overall goals of model-based, petascale computing, and of NEES and E-Defense.

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