Report of the

First Research Meeting of NHERI and NIED/E-Defense Collaborative Research on Earthquake Engineering

Kobori Research Complex

KI Building

Tokyo, Japan

October 30 and November 1, 2017

Convened by

NHERI Network Coordination Office (NCO)

and

National Research Institute for Earth Science and Disaster Resilience (NIED)

November 2017

PREFACE

On July 13, 2017 a new phase of the research collaboration on earthquake engineering between US and Japan got off the ground with the signing of the Letter of Agreement between Purdue University, on behalf of Natural Hazards Engineering Research Infrastructure (NHERI), and the NHERI Network Coordination Office (NCO), and the National Research Institute for Earth Science and Disaster Resilience (NIED) on earthquake engineering research using E-Defense and NHERI facilities. The signing of the agreement took place during the First Planning Meeting held July 13 and 14 of 2017. The objectives of this meeting were to discuss the details of the new research collaboration and implementation process. In addition, a follow-up meeting to determine the initial research activities was recommended to allow researchers to submit proposals to NSF in time to affect collaboration with the first test at E-Defense in October-November of 2018.

The First Research Meeting of NHERI/E-Defense Collaborative Research on Earthquake Engineering was convened on October 31 and November 1 of 2017 at the Kajima Kobori Research Complex, KI Building in Tokyo. At this meeting participated leading researchers from both countries as well as representatives from government agencies to discuss in plenary and breakout sessions the plans for NHERI and NIED/E-Defense collaboration.

This report contains a summary of the discussions and resolutions of this meeting.

Conveners

Koji Suzuki
Executive Director, National Research Institute for Earth Science and Disaster Resilience
(NIED)

Dr. Koichi Kajiwara,
Director, Hyogo Earthquake Engineering Research Center (E-Defense), National Research Institute for Earth Science and Disaster Resilience (NIED)

Dr. Masayoshi Nakashima,
President, Kobori Research Complex Inc.

Prof. Julio Ramirez,
Director, NHERI Network Coordination Office Purdue University

Prof. Stephen Mahin,
Director, NHERI Computational Modeling and Simulation Center,
University of California, Berkeley

ACKNOWLEDGEMENTS

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SUMMARY OF THE FIRST PLANNING MEETING OF THE NHERI/E-DEFENSE COLLABORATION ON EARTHQUAKE ENGINEERING RESEARCH

The First Research Meeting of the NHERI/E-Defense Collaboration on Earthquake Engineering on October 31 and November 1, 2017 was attended by 23 participants from the US and 18 from Japan. There was great interest on both sides in research collaborations as part of the Tokyo Metropolitan Resilience Project, Sub-Project C: *Collection and Synthesis of Data Regarding Structural/Non-structural Combined Performance and Damage Evaluation*, under the direction of Prof. Akira Nishitani and Dr. Koichi Kajiwara, under the formal agreement between NHERI and NIED on earthquake engineering research using E-Defense and NHERI facilities.

The report includes a summary of the proceedings, the recommendations and resolutions reached by the participants breakout and plenary sessions. The appendices contain the list of participants and the meeting agenda.

Reports summarizing the recommendations and resolutions during the breakout sessions are presented under each theme. Finally, the overall workshop resolutions and recommendations for the next meeting are given in the final section of this report. In keeping with the Tokyo Metropolitan Resilience Sub-Project C meta-theme, the working groups met in concurrent breakout sessions on:

(a) Reinforced Concrete Structures;

(b) Steel Structures + Protective Systems;

(c) Densely populated residential district (Wood Structures); and

(d) Non-structural Components.

The list of participants and affiliations from the U.S. and Japan can be found in Appendix 1, and the agenda for the meeting in Appendix 2.

In the Opening Session Dr. Hayashi from NIED welcomed all the participants, followed by opening remarks from Dr. Takeuchi (MEXT) and Dr. Pauschke (NSF). A summary of the Planning Meeting of July 13 and 14, 2017, goals of this meeting and general instructions were given by President Nakashima and Prof. Ramirez. Nakashima. Next, Prof. Nishitani discussed the principal engineering challenges in Tokyo Metropolitan Resilience, followed by Dr. Kajiwara's presentation on the achievement of E-Defense. The morning plenary session concluded with a presentation by Prof. Ellen Rathje on the use of DesignSafe for collaboration and data publishing and Prof. Ramirez leading a general discussion on mechanisms of collaboration and providing instructions for breakout sessions.

The researchers reconvened at the first series of concurrent breakout sessions held under each team. During the 1.5 day workshop a total of four series of concurrent research breakout sessions were conducted. During the first series of breakout sessions the Japanese researchers shared information on the research program under each theme of the Sub-Project C with the participants from the U.S. The program in each theme was augmented with presentations by Profs. Bergman and Terzic on the RAPID Facility and the SimCenter. The presentations from the researchers of Japan can be found in DesignSafe-CI at the bottom of the page: https://www.designsafe-ci.org/facilities/nco/partnerships/nied/ as part of the presentations given during the planning meeting of July 13 and 14. The presentations from the researchers of the U.S. at the October 31 – November 1 meeting cab be found at:

https://www.designsafe-ci.org/data/browser/public/designsafe.storage.published//PRJ-1765

SUMMARY OF THE BREAKOUT THEME SESSIONS

Following the opening plenary session, the participants gathered for a series of breakout research meetings to discuss the possible collaborations under each theme.

Wood Structures

<u>Participants:</u>

Shiling Pei, Colorado School of Mines, USA (All Sessions); Chris Pantelides, University of Utah, USA (All Sessions); Christian Malaga, Imperial College London, UK (All Sessions); Andre Barbosa, Oregon State University, USA (All Sessions); Maria Koliou, Texas A&M University, USA (All Sessions); Takuya Nagae, Nagoya University, Japan (All Sessions); Joy Pauschke, NSF, USA (Session 1); Masayoshi Nakashima, Kobori Research Complex Inc. (Session 2); Akira Nishitani, Waseda University (Session 2); Vesna Terzic, California State University Long Beach (Session 2); Jeff Berman, University of Washington (Session 2); Hayashi Kazuhiro, Toyohashi Univ. of Technology (Session 2); Julio Ramirez, NCO, USA (Session 2).

<u>Recorders:</u> Maria Koliou & Andre Barbosa

<u>Summary of Individual Presentations</u>

Dr. Takuya Nagae made a presentation on the wood structure test task of the Tokyo Metropolitan Project. Two wood residential house specimens will be constructed and tested in December 2018 at the E-Defense shake table. The tests are designed to investigate realistic building performance on soil foundations through installation of two soil boxes with 1 m thick soil layers under the specimen. Two structural systems will be tested including a post-and-beam system and a light-framed wood system, both are representative of the construction practice of wood housing districts in Tokyo. The performance of the building system, including soil-structure interaction and the performance of utility lines entering the building from the foundation will be the focus of the test. The Japanese researchers are interested in

economic loss assessment and resilience evaluation of these existing building configurations. It is possible to incorporate U.S. side retrofits in these tests, but the test plan needs to be developed quickly. The test plan is scheduled to be finalized during the first half of 2018, likely in April. The buildings will be tested to collapse and the collapse margin of the system will be assessed.

Dr. Shiling Pei made a presentation developed by the U.S. and U.K. researchers on potential ideas of research collaboration with the Japanese researchers. The ideas initially presented include pay-load testing of advanced retrofit systems including post-tensioned rocking wall, wood buckling restrain bracing (BRB), and fiber glass polymer retrofit on wood surfaces. Testing of non-structural components such as curtain walls and piping systems was discussed as well. The presentation also highlighted the possibility to collaboration on numerical modeling of wood systems, resilience, functionality and economic loss assessment, and fragility development based on testing data. The U.S. researchers also introduced the on-going mass-timber building research in the U.S., particularly the NHERI Tall Wood Project and timber-concrete composite mass timber diaphragms.

The presentations in breakout Session 1 from both sides helped to inform workshop participants on the research interests on both sides and focused the subsequent discussion on viable collaboration activities that align with these interests.

During Session 2, additional presentations were given by representatives from the NHERI RAPID team and Sim Center team, and other U.S. participants, in order to inform the researchers on the resources available.

Summary of Discussions

There is an urgency for the collaboration on wood topics due to the timeline of the E-Defense experimental schedule. This timing issue was discussed intensively during the meeting. There are two approaches for collaboration regarding the physical tests. The first one is to conduct testing data collection for informing repair and recovery modeling and for payload testing on the wood building specimen, which can be focused on retrofit of the structural system or on testing of non-structural systems. The second approach is to collaborate on analysis and modeling using the data obtained from the test. The Japanese team expressed strong support on both approaches as long as sufficient resources can be obtained to support these efforts. Given the limited time for planning, the involvement of industry parties from both the U.S. and Japan is a logical step for payload testing. With heavy focus of industry participation in the Tokyo Resilience Project, it is encouraged that the U.S. counterpart(s) include industry and practitioners in the collaboration team proposed. On the other hand, collaboration on data analysis and subsequent modeling does not have a pressing timeline and can be planned via normal research funding mechanisms. Both the Japanese and U.S. researchers agreed on the importance of transferring the knowledge and data obtained from physical tests to resilience assessment at the community level, student training, as well as public outreach and dissemination of the research findings. The specific ideas generated from the discussion were summarized below:

- Payload testing structural: After the test program completed for the Tokyo Resilience Project, the U.S. researchers can attach further retrofit systems as developed in the U.S. to the testing building configuration for additional tests before the collapse test of the building. This will require involvement of industry for material and labor donation, as well as timely planning to finalize the retrofit plan before April 2018.
- Payload testing non-structural: Different designs of piping or other non-structural system can be tested as part of the original test. The test plan needs to be reviewed by the Japanese team first. It is critical to involve industry early in 2018 for this option to be successful.

- Deploy NHERI RAPID equipment for data collection on the original tests. The Japanese researchers showed strong support for this option and sharing of data afterwards. The data collected using the NHERI RAPID equipment will also be available for informing repair and recovery modeling efforts.
- Using test data to conduct risk assessment in terms of economic losses and downtime of the wood buildings tested, incorporate the project the information into a community level resilience model to study the performance of Tokyo residential city blocks. It is also desirable to conduct comparison of Japanese and U.S. cities in terms of different decision variables.
- Collaborate on numerical modeling and prediction (including blind prediction contests) using different modeling techniques. Collaboratively developing new numerical tools to better predict wood building behavior under earthquake loading.

Challenges: The main challenge of establishing collaboration on the wood research effort is the timing of the shake table tests. In a relatively short timeline, the researchers need to assemble a diverse international team consisting of representatives from academia, the wood industry, building designers, and architects to come up with a consensus solution that can be tested. Although some new structural and non-structural systems have been identified during the workshop, logistic challenge still needs to be overcome.

Action Items

The researchers identified the potential opportunities in conducting collaborative research on resilient wood building systems, especially by leveraging the specimen and data from the wood building tests scheduled in December 2018 at the E-Defense shake table. The following joint activities actions items are planned following the discussion:

1) Submitting a joint community proposal through NSF's RAPID program in a timely manner to develop a research and industry collaboration network needed to implement payload testing, as well as data exchange for the December 2018 wood building tests. This community proposal will be led by Maria Koliou from Texas A&M University.
2) Wood researchers from the U.S. side will develop individual or collaborative proposals through NSF's ECI or LEAP HI programs addressing research challenges that are of mutual interest of Japanese researchers. The identified proposal topics include, but are not limited to: (a) reuse of the E-Defense test data to quantify housing recovery at community scale; (b) investigate the seismic response of advanced wood lateral systems and curtain walls; (c) propose novel design methods for wood diaphragms; (d) develop performance-based design guidelines for new systems and seismic retrofit techniques; and (e) perform theoretical investigations on wood building collapse margins.
3) Christian Malaga from Imperial College London will seek potential funding opportunities from the UK and Europe to pursue wood building research collaborations, including participating in the RAPID proposal effort, soliciting interested industry parties from Europe to contribute to the pay-load testing in 2018, and developing collaborative proposals to EU/UK funding agencies.

Group Resolutions

1. Seismic performance of wood buildings has critical impact on urban community resilience in both Japan and the U.S. because of the widespread of wood construction in both countries.

2. Both Japanese and U.S. researchers will to seek opportunities to collaborate on experimental and analytical research that will improve the current understanding of earthquake performance of

wood building system, which includes existing building systems, new building systems, wood building retrofit technologies, and innovative modeling/prediction techniques, impact of non-structural systems, including mechanical, electrical, and plumbing systems on the building system resilience.

3. Through joint research projects between the U.S. and Japanese researchers, broader international collaboration between the two countries should be enhanced that include wood industry, housing construction industry, design communities, and the general public. This relationship-building will have a lasting positive impact on resilience of communities in both countries where wood material and systems are widely used as part of the civil infrastructure.

Reinforced Concrete Structures

Participants:

Japan. Koichi Kusunoki (co-leader), University of Tokyo. Yo Hibino, Hiroshima University. Izumi Nakamura, E-Defense, NIED.

US. Marc Eberhard, University of Washington(co-leader). Luis Ibarra, University of Utah. Remy Lequesne, University of Kansas. Mohamed Moustafa, University of Nevada, Reno. Julio Ramirez, Purdue University. Petros Sideris, Texas A&M University.

Recorders: Remy Lequesne, Petros Sideris

Summary of Individual Presentations

o Koichi Kusunoki
  ▪ The goals of Japanese RC tests are: (1) to modify an existing type of building system to make it more seismically resilient and suitable for city halls and other critical buildings, and 2) to

develop a system to monitor and assess damage for both structural and non-structural components during earthquakes.

- A nearly full-scale model of a three-story, reinforced concrete frame building will be tested in one direction on the E-Defense shake table. Companion component tests will also be performed to identify the final details.
- The structure will be designed for double the typical lateral forces to be consistent with Japanese practice for critical buildings. The model will be similar to current practice, in which the windows are surrounded by nonstructural reinforced concrete panels. To take advantage of the "nonstructural walls", the ends of the walls can be constructed to resist compression by removing the seismic gap. To reduce the tension strains in the reinforcement and to make it possible to satisfy an allowable stress limit on the steel reinforcement, the wall reinforcement can be terminated at end of panel.

- o Marc Eberhard
  - Both the US and Japan have large databases that provide information of column and beams during cyclic loading. This information can be used to interpret the data from the Japanese component tests.
  - Both Tokyo and Seattle are underlain by deep sedimentary basins, which can greatly modify the ground motions, leading to response spectra that can increase with increasing period. Such motions could be applied to the E-Defense structure. During the subsequent discussion, it was agreed that long-duration or near-faulty motions could be of interest too.
  - Keri Ryan, UNR, did not attend this meeting, but she proposed to evaluate performance of US curtain walls by placing these in some of the bays.

- o Luis Ibarra
  - The objective of the US-Japan collaboration is to achieve seismic resilience under the DBE. Japanese researchers intend to increase resilience by increasing the system's lateral strength.
  - The US side can propose a second building with the same dimensions of the Japanese building, but using US desirable lateral resistance methods to achieve resilience, according to US design codes. The US side may consider non-RC components to
- o Remy Lequesne
  - Interested in reducing the vulnerability of RC structures and improving our capacity for identifying structures most at risk of collapse.
  - Potential collaborations: Component tests investigating slenderness effects in wing walls, which are analogous to slender wall boundary elements, and axial load effects in columns subjected to very large axial loads and lateral displacements
- o Mohamed Moustafa
  - The goal of this presentation is to entertain the idea of extending ultra-high performance concrete (UHPC) to larger applications and show preliminary results for a bridge column case. The presentation triggered the discussion of potentially using UHPC for the slender nonstructural and wing walls attached to the main RC frame. UHPC can be potentially used for the wing walls to reduce the thickness will providing sufficient contribution to the flexural strength of columns and beams.
- o Petros Sideris
  - Based on the discussions with the Japanese delegates, Dr. Sideris suggestions focused on: (1) the installation of a second RC structure (next to the Japanese RC structure) having a different lateral resisting system with different connection and construction details to test its resilience capabilities, and (2) the installation of a post-tensioned lateral resisting system in the lateral

direction of the existing Japanese structure. Collaboration on simulation of structural damage can also be a major opportunity for long-term collaboration.

o Jeff Berman
  ▪ The NHERI RAPID Facility can be deployed not only to the field, but also to the E-Defense shake table.
  ▪ The facility has drones, Lidar, Laser, and UAS cameras, and the accompanying software and hardware to visualize 3D data. This equipment could be used to document instrument locations and structural damage.
o Vezna Terzic
  ▪ The NHERI SIM facility will provide the framework to simplify the PBE workflow by integrating various analysis software and performance data for components, buildings and regions
  ▪ The facility is offering to organize a blind prediction contest for the planned tests.

Summary of Discussions

The most promising collaboration activities were evaluated, based on expected cost, and based on the perceived interest on the Japanese and US sides.

Proposed Activity	Cost	Interest US/Japan
Prepare another high-performance building with US Design to compare with Japanese design (tested at same time on table)	Very expensive (>$700k)	High/High
Apply a larger number of input motions (Shape of spectrum, 3D, long duration, long period)	Low	High/High
Instrumentation and damage evaluation (NHERI RAPID)	Low	High/High
Blind prediction analysis (NHERI SIM)	Low	High/High
Installing US piping, finishing and/or curtain walls	Moderate	High/Moderate
Shake building in other direction with US proposed high-performance details to allow comparison	Moderate to High	High/Low

The plans for the RC building will be finalized in December 2018, so US researcher intending to proposed modifications to the structure would need to do that by October 2018 for small modifications and earlier for larger modifications.

During the discussions, the Japanese and US researchers agreed that there are many research areas that are of interest to both sides outside of the scope of this NHERI-NIED collaboration. Such long-term collaboration is of great interest to both communities.

<u>Action Items</u>

1. The U.S. side is encouraged to self-organize to develop a single, coordinated (collaborative) proposal to NSF to deploy the RAPID equipment to the E-Defense tests. This approach would allow the Japanese researchers to review a manageable number of reviews.

2. The NHERI SIM center is encouraged to contact Prof. Kusunoki and Prof. Nishitani to organize a Blind Prediction Contest.

3. To propose research that involves construction of a new structure or modifications of the Japanese structure, it is essential that US researchers prepare a proposal to meet the January 2018 proposal deadline. Individual US researchers interested in collaborating with Japanese researchers should contact Prof. Kusunoki and Prof. Nishitani before submitting a proposal.

<u>Resolutions</u>

The National Science Foundation should consider funding small, expedited, preliminary design projects that would allow US researchers to meet deadlines set by the Japanese testing schedule.

Steel Structures plus Protective Systems

Participants: M. Kurata, B. Simpson, V. Terzic, J. Berman, A. Nishitani, K. Hayashi, Y. Hori, L. Linderman, J. Caicedo, J. Zhang, S. Dyke, L. Fahnestock, Joy Pauschke (NSF) and Julio Ramirez (NCO)

Recorder: L. Linderman

Summary of Individual Presentations

2. Masahiro Kurata, Kyoto University – Holistic Assessment of Seismic Damage in Medical Facilities

    Main points:

    - A steel specimen will be tested at E-Defense to address the resilience of medical services in large earthquakes.
    - The specimen will model larger medical complexes by including two linked buildings: 2-3 story special moment frame and 3 story steel building fitted with friction pendulum bearings.
    - To address system resilience common medical non-structural components and water systems will be included and professionals will inspect the structure between loadings.

3. Jeff Berman, University of Washington – Ideas and RAPID Facility

Main points:

- Regions, such as the pacific northwest of the US, are susceptible to subduction type faults, which produce long-period ground motions.
- Current research has shown that long period motion impacts fragility functions for structures in the region.
- The NEHRI RAPID site offers Lidar scanning equipment to capture nonstructural damage and take measurements of the deformation field.

4. Vesna Terzic, Cal State Long Beach – Berkeley Sim Center

Main points:

- NEHRI Sim Center has participants throughout the US working on tools for probabilistic performance based engineering.
- The inclusion of test data and blind competitions can be used for uncertainty quantification.

5. Barbara Simpson, Berkeley/Oregon State University – Research Ideas

Main Points:

- Pseudo-static tests have shown that a 'Strongback' system acts as a spine to distribute energy to multiple stories and eliminate soft stories. Dynamic analysis will help establish their performance.
- To improve base isolation design, a hardening bearing could be used to limit demand under large magnitude events.

6. Jian Zhang, UCLA – Research Ideas for Protective Systems

Main points:

- Use the testing data on structural and non-structural performance to develop a performance-based implementation framework for protective devices.
- A self-powered MR damper that uses an EGM to produce power eliminates the concern of power failures during seismic events.

7. Lauren Linderman, Minnesota – Research Ideas for Sensing and Protective Systems

Main points:

- The E-Defense tests could be used to benchmark a real-time hybrid simulation test, in which both the sensors and isolation system could form the physical component.
- Model prediction in the presence of uncertainties sparks interest in robust estimation techniques and the optimal sensor set.

8. Juan Caicedo, University of South Carolina – Model Updating for Condition Assessment

   Main points:

   - Leveraging sensor measurements for condition assessment requires addressing the sensors, data, models, and uncertainty quantification.
   - Key questions emerge in how to handle large datasets, determine important data features, and leverage diverse data to update models.
   - One possible approach to address these questions is the use of probabilistic models for condition assessment.

9. Shirley Dyke, Purdue – Research in Hybrid Simulation and Damage Estimation

   Main points:

   - A research coordination network (RCN) for multi-hazard hybrid simulation has been established to broaden users and make theoretical improvements in the methods.
   - The E-Defense tests, data, and observations can be used to validate RTHS/HS testbed, which will build confidence in hybrid simulation and can be used to evaluate a broader range of protective systems.
   - The application of computer vision tools that can localize areas of interest.

10. Larry Fahnestock, Illinois – Topics of Interest and a Summary of Potential Collaborations

   Main topics:

   - A key issue for seismic steel structure designs is how to mitigate deficiencies in existing ductile systems including global stability.
   - New resilient system configurations, such as low-damage self-centering systems, have shown promise in development studies; larger scale testing in 3D, including interface with gravity systems and nonstructural components, could help these be used in practice.
   - A summary of potential collaborations identified throughout the talks was presented. The summary can be found in the group discussion.

Summary of Discussions

The discussion in the breakout group focused on four categories of potential collaboration: (i) test payloads, (ii) test specimen reuse, (iii) complementary test activities, and (iv) education/outreach. Additionally, sample project timelines were developed for project categories that could be considered time-sensitive. Additional details for each category are provided below.

(i)   Test Payloads
Payload projects would incorporate additional tools or components in the E-Defense testing. As a result, these are time sensitive for funding and would require US researcher(s) support in Japan at the time of

testing. Possible areas of collaboration include: additional sensors and associated system identification techniques, studying specific non-structural components, using RAPID tools to capture damage and deformation. For some of these project areas, coordination with the Japanese team during the planning team is essential.

To help in planning, a sample project timeline is provided:

- US research idea submitted to Japanese collaborator for initial review: July 2018
    - Schematic drawings / Test objectives / Basic sensor requirements / Loading level(s) / ground motion(s) / Data sharing expectations / Potential for Japanese collaboration (all as applicable)
- US researcher submits NSF proposal: September 2018 (include letter of collaboration from Japanese collaborator)
- US researcher obtains NSF funding: February 2019 (contact Japanese collaborator)
- Test planning visit to E-Defense: March 2019
- Payload concept finalized: June 2019
- Instrumentation plan finalized: January 2020
- Bids for test specimen fixtures (if integrated w/ frame): April 2020
- Begin instrumentation installation: September 2020
- US researcher(s) in residence at E-Defense: August-November 2020
- Testing: November 2020

Note: this timeline is intentionally conservative; for a less intrusive payload, later proposal submission may be feasible (Jan. 2019)

(ii)   Test Specimen Reuse
While the special moment frame will likely be tested to failure, the base isolated structure should sustain minimal damage. The base isolated structure could potentially be reused for additional testing. Possible research areas of interest for the test structure include: incorporating novel lateral systems (rocking frame, self-centering braces, or spine configuration), evaluating smart base isolation by incorporating dampers, implementing vertical isolation systems. For specimen reuse, the project funding and design is extremely time sensitive and will require US researcher(s) support in Japan.

To help in planning, a sample project timeline is provided:

- US research idea submitted to Japanese collaborator for initial review: November 30, 2017
    - Schematic drawings / Test objectives & time expectations (# of testing days) / Basic sensor requirements / Loading level(s) / ground motion(s) / Data sharing expectations / Potential for Japanese collaboration
- US researcher submits NSF proposal: January 2018 (include letter of collaboration from Japanese collaborator)
- US researcher obtains NSF funding: August 2018 (contact Japanese collaborator)
- Test planning visit to E-Defense: October 2018
- Design concept finalized: February 2019
- Instrumentation plan finalized: January 2020
- Bids for test specimens: April 2020
- Begin instrumentation installation: September 2020
- US researcher(s) in residence at E-Defense: June-November 2020

- Testing: November 2020

Note: The cost of testing at E-Defense is not negligible and costs should be discussed with the Japanese collaborator prior to proposal submission.

(iii)   Complementary Test Activities

Collaboration activities do not require on-site interaction with the E-Defense testing but could leverage the data collected from the full-scale and component-level testing. Such test data could be used for investigating model validation, model updating, or condition assessment techniques. The sensor data quality and repeated seismic testing present an opportunity for uncertainty quantification. Additionally, hybrid simulation tests could be done in conjunction with the testing to validate hybrid test approaches. While hybrid simulation is not a popular research area in Japan, current researchers are starting to express interest in the field.

Education/Outreach

There is significant interest in working with the NHERI Sim Center to offer blind prediction contests based on the experimental tests. These could exist in several phases: pre-test, updated based on partial data, and post-test 'predictions'. An interesting idea would be to hold 'real-time' blind prediction based on the most recent test data to limit the computational complexity of the methods. A proposed outline of the different phases is provided:

- Announce competition and overall parameters: February 2020
- Distribute detailed information: October 2020
- Phase 1, Submit pre-test blind prediction: November 2020
- Testing: November 2020
- Phase 2, Submit updated predictions based on partial (elastic) test data: November 2020
- Distribute test results: December 2020
- Phase 3, Submit post-test updated "predictions": February 2021

Resolutions

1. Educate US researchers about collaboration opportunities (and timelines) and encourage proposals in three classes discussed: test payloads, test specimen reuse and complementary tests / simulations
2. Encourage proposals to collaborate at E-Defense
3. Organize blind prediction competition
4. Encourage collaboration through personnel exchanges (faculty / students / post-docs)
5. Explore opportunities for joint research and publications
6. Data will be shared to the greatest degree possible

Action Items (linked to Resolutions)

1. Disseminate report from this meeting, including types of potential projects and required schedules (everyone; NCO; Dyke to share at MECHS meeting)
2. Proposals to be developed: use RAPID at E-Defense (Dyke and Berman); predictive modeling / simulation (Caicedo and Linderman); smart base isolation (Zhang)
3. Coordinate blind prediction activities (SimCenter)

4. Disseminate information about existing programs for funding US researchers to visit Japan (e.g. EAPSI, JSPS)
5. Develop database of researchers and active projects in both US and Japan (CI develop / NCO disseminate)
6. Logistics / policies to be established by leadership (NHERI / NIED)

Non-Structural Components

Participants: Koichi Kajiwara, Eduardo Miranda, Eiji Sato, Tali Feinstein, Yamato Tanaka, Ellen Rathje, Kentaro Tabata, Koji Suzuki, Joel Challender, NIED

Recorders: Eduardo Miranda, and Tali Feinstein

Summary of Individual Presentations

- o Title Function-Maintenance in Indoor Space
- o Presenter: Dr. Eiji Sato, NIED
- o Main points: Provided brief statistics of cause of injuries in the 1995 Hyogo-ken-Nambu (Kobe) and 2016 Kumamoto earthquakes. Emphasis will be on indoor nonstructural components and contents. Described the series of reusable "verification units" that will be used at E-Defense and provided overall schedule.

- o Title: Opportunities and Ideas for Research Collaboration Towards Resilient Nonstructural Components
- o Presenter: Prof. Eduardo Miranda, Stanford University
- o Main points: Briefly summarized three main reasons why nonstructural components and systems are very important. Described the three research challenges, as expressed in NHERI's Science plan, and how they relate to nonstructural components and systems. Provided examples of five different ideas of possible research collaborations with NIED/E-Defense.

- o Title: Ideas for Collaboration on Anchoring Floor Supported Equipment and Contents
- o Presenter: Tali Feinstein, UC Berkeley
- o Main points: Provided a summary of an anchored nonstructural test done in Berkeley. Presented three areas for optional collaboration relating to test design, component payload and analysis of result to improve loss estimation of nonstructural components.

Summary of Discussions

During the NHERI/E-Defense Joint Research Planning Meeting we had four different breakout sessions in which presentations and discussions were made by both NHERI and NIED/E-Defense investigators. In the first round of discussions, Japanese investigators from NIED/E-Ddefense provided excellent background and motivation for theme 4 of the Tokyo Metropolitan Resilience Project focused on nonstructural components. In particular, they showed that the majority of the injuries in the 1995 Hyogo-ken-Nambu (Kobe) and 2016 Kumamoto earthquakes were not from people being buried under structural elements but rather being buried or hit by glass or metal from nonstructural components or buried/hit by building contents such as furniture and electrical appliances. They mentioned that emphasis on the project will be on indoor contents and some architectural nonstructural components. The project contemplates testing a series of reusable units and the scope could include the testing of individual units, testing units stacked vertically or testing units assembled side by side to create large horizontal spaces. The main types of occupancies being planned are residential and office. They anticipate to interact with manufacturing associations in Japan such as associations of manufacturers of ceilings, partitions, raised floors, office equipment. An additional effort would be dedicated to assessment method for indoor damage using sensors, and new methods for damage reduction. Theme 4 has a 5-year schedule with year 1 in 2017 for planning of the framework and testing during year 5 in 2021.

The Japanese investigators expressed their main interests in a US contribution in developing a loading protocol, improving loss estimations of nonstructural components and data sharing (exchange data collected from previous earthquakes on both sides). The loading protocol should include a variety of input motions that will be of most interest. The input motions are expected to vary from service level, effecting mostly unconstrained components, through to design level or higher to investigate anchored components and other damage reduction methods.

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Investigators from the U.S. discussed how earthquake resistant design of nonstructural components is lagging both in the United States and in Japan with respect to that of the structure. They provided three reasons why research in this area so important: (1) Damage of nonstructural components can lead to serious injuries and even loss of life; (2) damage of nonstructural components and systems often leads to partial or total loss of use of buildings including those of critical facilities; and (3) damage of nonstructural components can lead to very large economic losses. Three main grand challenge areas identified in the NHERI 5-year Science Plan (available on line at the DesignSafe website) but in the context of nonstructural components and systems were discussed. Then, six different collaboration ideas related to the three grand challenge areas were presented and discussed.

Theme 4 is not involved in the other themes efforts, and installation of a nonstructural payload has been discussed in every theme separately. The main conclusion is that all themes plan on including some nonstructural components with budget as their limiting factor. Thus, they are in general open to any contribution on the American side.

Action Items

A list of the main areas that were identified for possible collaboration during the Oct 31-Nov 1, meeting at Tokyo is provided in this section. This list is meant to provide more information for researchers in the U.S. interested on submitting research proposals to NSF involving collaboration with E-Defense in theme 4 - Nonstructural components.

Areas of possible NHERI/E-Defense collaboration related to nonstructural components:

1. **Testing of nonstructural components at E-Defense by NHERI investigators**. Three possible types of testing were identified: (1) Design, installation, instrumentation and testing of nonstructural components fully using one of the reusable units; (2) Installation and testing of a series of nonstructural components and systems within a portion of a unit (e.g., a ceiling, piping, duct, light-fixtures system); and (3) Installation and testing of individual components (e.g. ceilings, partitions, a specific type of building content or equipment, etc).

2. **Testing of nonstructural components and systems at NHERI facilities**. The nonstructural components and/or systems would be the same or related to those that will be subsequently tested at E-Ddefense. This could involve, for example, conventional nonstructural components to determine their fragility or the testing of new more resilient nonstructural components.

3. **Simulation, data collection and data sharing** of nonstructural testing that will be conducted at E-Ddefense. Here simulation is broadly defined not only referring to the response simulation of the nonstructural components but also damage estimation and the simulation of consequences of the damage such as the potential to cause injuries, possible partial or total loss of use of the facility, and loss estimation. It is encouraged to conduct the simulation of nonstructural components and systems using software and workflows available at the SimCenter NHERI facility at UC Berkeley. Similarly, some of the data collection prior to the test, during the test and after the test could involve making use of emerging technologies and equipment available at the NHERI Rapid facility at the University of Washington. NEHRI investigators would be uploading and sharing data at the NHERI DesignSafe facility.

4. To **collect, organize and share information** on nonstructural components to be tested at E-defense in order to conduct **competitions of prediction of response and damage**. The simulations/predictions would be submitted by participants prior to the distribution of response

information such that they would be, so-called, blind predictions. These blind analysis contest would be similar to those that have been successfully organized for structures such as the blind analysis contest of the 5-story steel building that was tested at E-defense in 2008. Information and submissions would be uploaded at DesignSafe HNHERI facility. NHERI investigators are encouraged to conduct their simulations using simulation software and workflows available at the SimCenter NHERI facility at UC Berkeley.

5. As part of any NHERI/E-Defense collaboration, **exchange of personnel**, in particular of young investigators to travel and spending time at E-Defense is encouraged.

6. **Developing loading protocols** for nonstructural testing. The Input motion should include both Japanese and American characteristics of ground motion, and provide the base for evaluating the behavior of loose and attached nonstructural component.

Resolutions

Theme IV of the Tokyo Metropolitan Resilience Project subproject C provides a unique opportunity for U.S.-Japan collaboration between NIED/E-Defense and NHERI in the area of nonstructural components and systems. Being the last of the 4 major testing planned at E-defense, it provides more time for planning such collaboration. Furthermore, unlike other themes that primarily involve the testing of one major specimen, here a number of reusable units have been planned to facilitate the testing and simulation of different assemblies of nonstructural components and systems corresponding to different types of occupancies and being able to test them under different loading conditions. This provides an excellent framework not only for various kinds of testing but also simulation.

Overall Workshop Resolutions

Based on the presentations, discussions and deliberations, the participants of the First Research Meeting of the NHERI and NIED/E-Defense Collaboration on Earthquake Engineering Research of October 31 and November 1 of 2017 formulated and unanimously adopted the following specific resolutions found in this section. In addition, resolutions adopted under each theme can be found at the end of each of the theme

1. The participants agree to continue to explore this collaboration under the framework developed at the planning meeting of July 13-14, 2017 and believe that NHERI and NIED/E-Defense collaboration by the U.S. 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.

2. The participants agree that annual research collaboration meetings to plan, accelerate the exchange of information and coordinate research should be planned at least until 2021. The final venue and duration of such meetings will be selected to meet the needs of the project collaboration. Availability on that period of time of the Japan side will be shared at the earliest possible date with the U.S. side to schedule the meeting and facilitate participation of the Japan and U.S. government representatives. Material to be discussed and/or shared will be distributed to the participants in advance of the meeting.

It was agreed that it is important that regular joint meetings be held to plan future tests and projects around Sub-Project C directed by Prof. Nishitani and Dr. Kajiwara under the Tokyo Metropolitan Resilience Project led by Prof. Hirata. Following this first research collaboration meeting. Annual 2-day meetings preferable in conjunction with the four planned tests be held at the E-Defense Miki City Facility or in Kobe, Japan. The possible goals of those meetings would be to: (1) identify the appropriate characteristics of the research to be performed, (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 the information obtained from ongoing projects and promote dissemination of research findings and their use in education and practice.

3. Data Sharing-Pursuant to Item 11 of the agreement: the data and metadata derived from the experiments of joint research shall be stored in an electronic data repository as it is recorded for immediate access by members of the joint research team. Unless otherwise agreed by NHERI and NIED, data publication from U.S. and Japan collaboration projects under the scope of the Tokyo Metropolitan Resilience Project, Sub-Project C shall be in accordance with NHERI Data Curation Guidelines. US and Japanese researchers will make the most possible use of DesignSafe for sharing experimental data and research results. They will publish datasets with DOIs on DesignSafe based on a timetable approved by Japanese researchers.

4. Accelerate the transfer of technology.

Efforts to increase involvement of design professionals and dissemination of findings to various stakeholders should continue. It is clear that there is a significant benefit of involving design professionals in the formulation of research plans, conduct of research and interpretation of findings. Collaborate in joint publications to disseminate findings is expected to increase the value and impact of the research.

5. Facilitate Data exchanges.

Efforts should be increased to take advantage of currently available data. Large efforts have been undertaken to carry out the tests that have been conducted at E-Defense and to analyze the data to validate underlying theory, improve analytical simulations tools and models, develop recommendations and guidelines that impact engineering design and evaluation. However, there is believed to be value in expanding the scope of such evaluations, especially by having groups of U.S. and Japanese researchers examine data from individual tests but perhaps more importantly to compare and contrast data obtained from multiple tests and numerical analyses. This effort is thought to have a high value for relatively modest cost.

6. Facilitate Personnel Exchanges.

It is desired to increase collaboration by identifying existing and perhaps initiating new mechanisms that would enable exchange of researchers from the U.S. to Japan, and from Japan to the U.S. In particular, it is recommended that exchange of students and junior researchers to participate in particular efforts focusing on synthesizing, analyzing and interpreting available data, or participate in planning and conduct of tests would be highly beneficial.

Closure

The participants believe that the 1st Research Collaboration Meeting of the new phase of collaboration on Earthquake Engineering between researchers from the U.S. and Japan was highly successful, and that NSF and MEXT should be congratulated for providing the earthquake engineering community with cutting-edge experimental tools that will substantially accelerate progress towards the important goals of earthquake loss reduction.

Funding agencies are encouraged to provide needed resources. Given the importance of the research to be proposed, and the benefits of leveraging resources available in the U.S. and Japan, appropriate funding agencies in the U.S. and Japan are encouraged to provide adequate funding and other support needed to realize the benefits of this new phase of the U.S. and Japan research collaboration under the umbrella of the agreement between NHERI and NIED on earthquake engineering research using E-Defense and NHERI Facilities.

The participants also appreciate and heartily thank NIED Executive Director Mr. Koji Suzuki, President Nakashima and the professional staff of tNIED and the Kobori Research Complex Inc. for their efforts in hosting this successful meeting. The support of the National Science Foundation is also greatly appreciated.

The participants agreed that the research collaboration meetings should reconvene in Kobe City in conjunction with the first test of the Tokyo project at E-Defense in November/December of 2018.

Appendix 1: List of Participants

Name	Affiliation	Position	Theme
<td colspan="4">   <US Side></td>
1. Andre Barbosa	Oregon State University	Assistant Professor	Wood
2. Jeffrey Berman	University of Washington	Associate Professor	NHERI RAPID and Steel + Protective Systems
3. Juan Caicedo	University of South Carolina	Professor	Steel + Protective Systems
4. Shirley Dyke	Purdue University	Professor	Co-Leader, Steel + Protective Systems
5. Marc Eberhard	University of Washington	Professor	Leader, Reinforced Concrete
6. Larry Fahnestock	University of Illinois at Urbana-Champaign	Associate Professor	Co-Leader, Steel + Protective Systems
7. Tali Feinstein	UC Berkeley	PhD student	Non-Structural Components
8. Luis Ibarra	The University of Utah	Associate Professor	Reinforced Concrete
9. Maria Koliou	Texas A&M University	Assistant Professor	Wood
10. Lauren Linderman	University of Minnesota	Assistant Professor	Steel + Protective Systems
11. Remy Lequesne	University of Kansas	Assistant Professor	Reinforced Concrete
12. Christian Malaga	Imperial College London	Senior Lecturer	Wood
13. Eduardo Miranda	Stanford University	Professor	Leader, Non-Structural Components
14. Mohamed Moustafa	University of Nevada, Reno	Assistant Professor	Reinforced Concrete
15. Chris Pantelides	University of Utah	Professor	Wood
16. Joy Pauschke	National Science Foundation	Program Director, Engineering for Civil Infrastructure and Natural Hazards Engineering Research Infrastructure	---
17. Shiling Pei	Colorado School of Mines	Assistant Professor	Leader, Wood
18. Julio Ramirez	Purdue University	Professor and Director and PI NHERI-NCO	NHERI-NCO and Reinforced Concrete
19. Ellen Rathje	University of Texas, Austin	Professor and PI NHERI DesignSafe-CI	NHERI DesignSafe-CI
20. Petros Sideris	Texas A&M University	Assistant Professor	Reinforced Concrete
21. Barbara Simpson	UC Berkeley / Oregon State University	PhD candidate	Steel + Protective Systems
22. Vesna Terzic	California State University Long Beach	Assistant Professor	NHERI SimCenter and Steel + Protective Syst
23. Jian Zhang	UCLA	Associate Professor	Steel + Protective Systems
<td colspan="4">   <Japan Side></td>
Ei Takeuchi	Ministry of Education, Culture, Sports, Science and Technology (MEXT)	Director, Earthquake and Disaster-Reduction Research Divisions	---
Yamato Tanaka	Ministry of Education, Culture,	Deputy Head of MEXT	---

	Sports, Science and Technology (MEXT)	Disaster Mitigation Section	
Haruo Hayashi	NIED	President	---
Masayoshi Nakashima	Kobori Research Complex Inc.	President	---
Akira Nishitani	Waseda University	Professor	---
Koichi Kajiwara	National Research Institute for Earth Science and Disaster Resilience (NIED)	Director of E-Defense	---
Kazuhiro Hayashi	Toyohashi Institute of Technology	Assistant Professor	Co-Leader, Non-Structural Elements
Yo Hibino	Hiroshima University	Assistant Professor	Co-Leader, Reinforced Concrete
Yasuke Hori	Kobori Research Complex Inc.		
Yohsuke Kawamata	National Research Institute for Earth Science and Disaster Resilience (NIED)	Researcher	Co-Leader, Steel + Protective Systems
Masahiro Kurata	Kyoto University	Associate Professor	Co-Leader, Steel + Protective Systems
Koichi Kusunoki	University Tokyo	Associate Professor	Leader, Reinforced Concrete
Takuya Nagae	Nagoya University	Associate Professor	Leader, Wood
Izumi Nakamura	National Research Institute for Earth Science and Disaster Resilience (NIED)	Chief Researcher	Co-Leader, reinforced Concrete
Eiji Sato	National Research Institute for Earth Science and Disaster Resilience (NIED)	Chief Researcher	Leader, Non-Structural Components
Kentaro Tabata	National Research Institute for Earth Science and Disaster Resilience (NIED)	Chief Researcher	---
Joel Challender	National Research Institute for Earth Science and Disaster Resilience (NIED)	Interpreter	---
Koji Suzuki	National Research Institute for Earth Science and Disaster Resilience (NIED)	Executive Director	---

Appendix 2: Meeting Agenda

NHERI /E-Defense Joint Research Planning Meeting
10-31-17 and 11-1-17

Dates and Times: from 9:30 AM of Tuesday October 31 to noon of Wednesday, November 1, 2017

Location: Kobori Research Complex Inc. (Akasaka, Tokyo)

Program

DAY 1 (Tuesday, October 31)

First Session (chaired by Nakashima and Ramirez)

9:30 – 9:40   Welcome Remarks (NIED: Hayashi)

9:40 – 10:00   Greetings from Japan (MEXT: Takeuchi) and USA (NSF: Pauschke)

10:00 – 10:20   Summary of the Planning Meeting of July 13 and 14, 2017; Goal of this meeting and general instructions (Ramirez & Nakashima)

10:20 – 10:30   Break

Second Session (chaired by Nishitani and Ramirez)

10:30 – 10:50 Engineering Challenges in Tokyo Metropolitan Resilience

Overview (Nishitani, 7 min + 3 min discussion)

Achievement of E-Defense (Kajiwara, 7 min + 3 min discussion)

10:50 – 11:05   Using DesignSafe for Collaboration and Data Publishing (Rathje)

11:05 – 11:15   General discussion on mechanisms of collaboration and instructions for breakout sessions (Ramirez & Nakashima)

11:15 – 11:20   Break

Breakout Research Sessions (4 Sessions- one in each Theme)

11:20 - 12:30 Breakout Session Part 1

Theme 1: Wood (Nagae: 10 min + 5 min discussion, Presentations from USA side)

Theme 2: Reinforced Concrete (Kusunoki: 10 min + 5 min discussion, Presentations from USA side)

Theme 3: Steel + Protective Systems (Kurata: 10 min + 5 min discussion, Presentations from USA side)

Theme 4: Nonstructural Elements (Sato: 10 min + 5 min discussion, Presentations from USA side)

12:30 – 13:30 Lunch

Breakout Research Sessions (4 Sessions- one in each Theme)

13:30 – 15:00 Breakout Session Part 2

15:00 – 15:10 Break

15:10 – 16:40   Breakout Session Part 3

16:40 – 16:50   Break

Third Session (chaired by Kajiwara and Rathje)

16:50 – 18:00   Joint Session to discuss main findings and conclusions from Breakout Sessions and Instructions for next morning's break out sessions and closing session with next steps

18:30 –   Dinner

DAY 2 (Wednesday, November 1)

<u>Breakout Research Collaboration, Final Session</u>

9:30 –10:40   Breakout Session Part 4: Theme: Discussions for US-Japan Collaborations and Preparation of Breakout Theme Session Reports and Final Resolutions

10:40 – 10:50 Break

<u>Closing Session (chaired by Nakashima and Ramirez)</u>

10:50 – 11:40 Presentations of Resolution Drafts and Adoption of Resolutions

11:40 – 12:00   Closing remarks(MEXT, NIED, NEHRI, NSF)