Total Project Planning – Case Study 1: PCI Building

Dr. Robert B. Fleischman
University of Arizona
14 December 2015
Presentation Outline

- Overview of Projects
- Research Conceptual Phase
- Proposal Planning Phase
- Project Pre-Test Phase
- Project Testing Phase
- Project Post-Test Phase
Overview of Projects

- Project 1: Development of a Seismic Design Methodology for Precast Concrete Diaphragms (DSDM)
  - Pre-NEES/GOALI
    - 2005-2009
  - $1.5M Funds
    - $467K GOALI
    - $101K NEES
    - $415K CPF
    - $365K PCI
    - $168K Industry
  - $1.1M Other
    - $335K NEES O&M
    - $583K In-Kind
    - $190K University
Overview of Projects

➢ Project 2: NEESR-Inertial Force-Limiting Floor Anchorage Systems for Seismic Resistant Building Structures (IFAS)

- NEESR
  - 2011-2015
  - $1.2M NEESR Grant
- $790K Other
  - $312K NEES O&M
  - $ 50K NEES Supp.
  - $ 50K PCI/PCI West
  - $ 58K Industry
  - $320k Univ./Ext. Student Support
Objective and Deliverables

Project 1: DSDM (GOALI/Pre-NEES)

• **Deliverable**: A new seismic design methodology for precast concrete diaphragms.
• **Research**: Evaluate existing designs for typical construction.
• **Outcome**: New design provisions approved for inclusion in ASCE 7-16 and Part 3 of the 2015 NEHRP Provisions.

Project 2: IFAS (NEESR)

• **Deliverable**: Demonstrate an innovative system to reduce inertial forces in building structures during earthquakes.
• **Research**: Develop a new seismic-resistant system.
• **Outcome**: Successful demonstration of a system prototype.
Phase 1: Research Conceptual Phase

 Role of the Shake Table Testing:

• What key scientific role in the overall project does the shake table test serve?
  – Sketch out the project w/out the shake table test, or with a smaller shake table test to justify the need for the test.

• What is the objective of the shake table testing?
  – Name the specific data products the testing will produce, and how this will be used in the project and/or future research.
Project 1: DSDM (GOALI/Pre-NEES)

• Rationale for shake testing:
  • Boundary Conditions of a distributed system such as a diaphragm do not lend themselves to concentrated actions (e.g. from actuators)
  • Finite Element Analysis can produce realistic boundary conditions, but calibrated models are required for code change.

• Rationale for NEES@UCSD Shake Table:
  • Scaling of precast elements, reinforcement and connectors has lower limit of 1/3rd to ½ scale before testing details become “toys”
  • Observed diaphragm failures in precast diaphragms have historically occurred in longer span floor decks
Project 2: IFAS (NEESR)

- Rationale for shake testing:
  - A new concept is fine in abstract but construction industry is conservative and requires physical demonstration for proof of concept.
  - A key aspect of proof of concept for the prototype system is its ability to handle articulation of the three dimensional structure.

- Rationale for NEES@UCSD Shake Table:
  - The inertial force tributary to an isolated lateral force resisting system (LFRS) element (as well as the P-\(\Delta\) effect) is based on a significant floor area
  - A key aspect of the system is the participation of the gravity columns as the floor system becomes partially decoupled from the primary LFRS elements.
Role of Shake Table Testing

• What is the appropriate testing scheme for the project?
  • Laboratory-type (isolated portion, slice or component)
  • Structural System

Conceptual Phase

NHERI @ UCSD Workshop, 14-15 December, 2015
After drawing up your conceptual research plan, contact UCSD:

- Is the planned test realistic?
- Is the draft budget appropriate?
- Is the required shared use available?
- Is the needed instrumentation available?

Both projects presented here involved a UCSD co-PI
Research Team Composition

Producer Members

University of California
San Diego
Jose’ Restrepo, PI

Lehigh University
Clay Naito, PI
Richard Sause, Co-PI

Industry Liaison
S. K. Ghosh, Co-PI
DSDM Task Group

Industry Advisory Panel

Dichuan Zhang and Ge Wan, University of Arizona
Liling Cao, Rui Ren, Wesley Peter, Lehigh Univ.
Matt Schoettler, Carlos Blandon, Andrea Belleri, UCSD
Mario Rodriguez, Humberto Cabrera Roa, UNAM

University of Arizona
Robert Fleischman
Consortium Leader

University of Arizona
Consortium Leader

NHERI @ UCSD Workshop, 14-15 December, 2015
Research Team Composition

**Proposal Planning**

### IFAS

**The University of Arizona**
- Dr. Robert Fleischman, PI
- Zhi Zhang, Ph.D. student
- Ulina Shakya, Ph.D. student
- Anshul Agarwal
- Austin Houk, REU
- Scott Kuhlman, REU
- Mackenzie Lostra, REU
- Daniel Lizarraga, REU
- Fernando Gastelum, REU
- Patrick Hughes, REU
- Ziyi Li, REU

**University of California, San Diego**
- Dr. Jose Restrepo, Co-PI
- Arpit Nema, Ph.D. student
- Gabriele Guerrini
- David Duck
- Nelson Angel
- Armita Pebdani
- Steve Mintz, Ph.D. student

**Lehigh University**
- Dr. Richard Sause, Co-PI
- Georgios Tsampras, Ph.D. student
- Alronil Pacheco, REU (San Jose State University)

**Nazarbayev University**
- Dr. Dichuan Zhang

**Academic collaborators**

**Seismic Design Consultants**
- Dr. Jose Restrepo, Co-PI
- Arpit Nema, Ph.D. student
- Gabriele Guerrini
- David Duck
- Nelson Angel
- Armita Pebdani
- Steve Mintz, Ph.D. student

**Tipping Mar**
- David Mar

**Rutherford + Chekene**
- Joseph Maffei
- Saeed Fathali

**Technical University of Bari**
- Dr. Giorgio Monti
- Dr. Alessandro Scodeggio

**University of Rome**
- Dr. Giorgio Monti
- Dr. Alessandro Scodeggio

**IFAS**

**Educational collaborators**

**Joe Maffei Association**
- Dr. Beppe Marano
- Dr. Giuseppe Quaranta

**Utterback Middle School**
- Gricelda Meraz

**K12 partner**
- Utterback Middle School

*IFAS*

*University of Arizona*

*University of California, San Diego*

*Lehigh University*

*Nazarbayev University*

*Seismic Design Consultants*

*Tipping Mar*

*Rutherford + Chekene*

*Technical University of Bari*

*University of Rome*

*Joe Maffei Association*

*Utterback Middle School*

*K12 partner*
Proposal Planning

Practical Considerations:

• What is the needed extent of the specimen (structural system, building slice, component, etc.) to obtain the behavior desired for study?

• What are the lower bound limitations on scaling of elements to still produce the desired behavior?

• How do the answers to the above two questions square with the geometry and the capacity of the UCSD NHERI Shake Table?
Practical Considerations

Proposal Planning

extends 15.5 ft each side

25 ft wide platen
Practical Considerations

Proposal Planning

7” thick, in situ concrete topping for stiff and strong diaphragm

outriggers to provide counterbalance weight to resist overturning... sliding on

pre-compressed hydrostatic slider bearings on mirrored-finish stainless-steel plates
Budget Considerations:

- What is the target budget range of the overall proposal?
- What portion of the overall can be $ number can be realistically apportioned to the shake table test?
- What industry partners, champions or other funding sources can be identified to rely on for contributions, in-kind engineering, materials, components, erection, construction, etc.?
Industry Partnerships

Proposal Planning

DSDM

- $415K CPF
- $365K PCI
- $168K Industry
- $583K In-kind

NEES

PCMAC

S PancrEte®

SPANCRETE®

STRUCTURAL & ARCHITECTURAL PRECAST

Quality • Service • Durability

Metromont

Tindall

Better Building Through Technology

NHERI @ UCSD Workshop, 14-15 December, 2015
Proposal Planning

Scheduling shake test within project duration

• Early (Year 1) – Pros and Cons
  – **Pro**: get to use shake table test data for most of the project
  – **Con**: not much planning, not much knowledge gained prior

• Late (Year 3) –
  – **Pro**: a lot of planning time, a lot of knowledge gained prior
  – **Con**: not much use of data during project

• Middle (Year 2)
  – Often the best compromise – able to do gain sufficient knowledge yet have time to utilize findings

• 3 year + 1 cost NCE – helps for these projects
Shake Table Test Scheduling

Phase I

UCSD

③ MDOF Dynamic Analysis

Arizona

② FE Pushover Analysis

Lehigh

① Full-Scale Detail Tests

④ 3D NLTDA

⑧ Trial Factor Evaluation

⑨ Prototype Structure Design Verification

Phase II

⑥ Scaled Shake Table Test

⑦ Model Calibration

Phase III

DSDM
Phase 3: Project Pre-Test Phase

➢ Your research team must multi-task 1st Year:
  • Obtain research findings needed to inform the shake table testing, including any component tests
  • Preliminary design shake table specimen
  • Perform analytical predictions to maximize odds shake table testing will produce desired results
  • Design and detail specimen; create drawings
  • Source materials including donations
  • Schedule specimen fabrication, erection, demolition
  • Create instrumentation plan
Project Pre-Test Phase

Logistics

- Trades - What tasks can be handled by the UCSD NHERI staff and what requires local contractors (riggers, demolition, special fabrication, etc.)?
- Manpower – REUs, budget or locate university or external funds for graduate students to spend extended time at site
- Communication - In the lead-up year to testing, establish regular web-conferences for shake table test planning (weekly for internal group, as needed with UCSD staff)
Logistics: Planning Meetings

DSDM Task Group Final Pre-Test Meeting, La Jolla CA
Logistics: Planning Meetings

NEESR IFAS Research Meeting #3 at R&C Offices

Saeed Fathali R&C
David Mar T&M
Jose Restrepo UCSD
Dom Campi R&C
RBF UA
Richard Sause LU
Joe Maffei JMA

Pre-Test Phase
Payload Projects

**Pre-Test Phase**

**System Identification:** Belleri, Restrepo, Conte

**Equipment Isolation Systems**
Henri Gavin, Duke

**GPS Building Monitoring**
Yehuda Bock, Scripps
Specimen Design

IFAS Half-Scale Specimen

- Involves design of system under study & structure
- Faithful similitude from evaluation structure was maintained on all parameters except two:
  1. Slab thickness was not scaled
  2. Floor-to-floor height was “under-scaled”
Specimen Design

Pre-Test Phase

IFAS Structure

Rubber Bearing

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Specimen Design

Pre-Test Phase

TRAD Structure

Roller Bearing

PSA

Dimensions:
- 38'
- 32'
- 23'
- 20'

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Test Repeatability

Pre-Test Phase

Precast rocking wall

- Embedded PL for IFAS RB
- Embedded slot for PSA for traditional
- Embedded plate for energy dissipater

Drawing created by Arpit Nema.
Specimen Design

Pre-Test Phase

Precast columns

Section A

Section B
Analytical Simulation

Project Pre-Test Phase
Analytical Simulation

Project Pre-Test Phase

Diaphragm Force

Diaphragm deflection

Test
Prediction

Time (s)

Test
Prediction

Time (s)
Analytical Simulation

Project Pre-Test Phase

NHERI @ UCSD Workshop, 14-15 December, 2015

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## Ground Motion Selection

*Project Pre-Test Phase*

<table>
<thead>
<tr>
<th>EQ Name</th>
<th>DT (s)</th>
<th>PGA [g]</th>
<th>Earthquake</th>
<th>Date</th>
<th>Station</th>
<th>Component</th>
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<td>0.005</td>
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<td>000</td>
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![Graph showing pseudo-acceleration vs. period with different spectral responses labeled: Berkeley design spectrum, Seattle design spectrum, T1, T2, ILAS, PSA, and SE05.](image-url)
## Testing Program

### Project Pre-Test Phase

<table>
<thead>
<tr>
<th>Phase I</th>
<th>TEST #</th>
<th>Ground-Motion</th>
<th>Level</th>
<th>Wall PT Ratio (E/WNS)</th>
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**Notes:**
- Phase I tests include a mix of seismic and non-seismic excitations.
- Phase II tests focus on structural response under dynamic loads.
- Phase III tests aim to evaluate performance under extreme conditions.

**Key Terms:**
- **PSA+:** Performance-based Seismic Assessment
- **Damper:** Additional damping devices installed in structures.
- **Roller Bearing:** Flexible supports allowing movement.
- **High Strength RC Wall:** Reinforced concrete walls designed for high performance.
Instrumentation Plan

Project Pre-Test Phase

Zero Floor Plan View:
1st Floor Columns Linear Pots

IFLFAAS Shake Table Test Instrumentation Layout

Drawn By: Scott Kuhlman
Graduate Student Researcher
University of Arizona

Sheet 6 of
Phase 4:  

Project Testing Phase

➢ **Four main stages of Testing Phase:**
  - Specimen Construction Stage
  - Specimen Instrumentation Stage
  - Shake Table Testing Stage
  - Specimen Demolition Stage

*Ironically Testing is typically only a small portion of the Testing Phase!*
Construction Phase

Project Testing Phase

Slab cast in place
Construction Phase

- Table time saving via use of elements created off-site
Construction Phase

Project Testing Phase
Stability during Construction Phase

Sway in EW direction

Sway in NS direction

Sway in NS direction

Buckle of SKT twisting

Local buckle in NS wall

Twisting

Twisting

Buckle of internal column in 1st floor

SET | TIME/FREQ
---|---
1  | 11.335
2  | 12.791
3  | 16.416
4  | 19.463
5  | 21.096
6  | 23.298
7  | 23.503
8  | 24.862
9  | 25.347
10 | 27.353

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Specimen Instrumentation Phase

LEVEL THREE: PRESTOPPED DOUBLE TEE SYSTEM
Student Participation

Specimen Construction/Instrumentation

Guerrini, UCSD PhD

Tsampras, Lehigh PhD

Agarwal, UA PhD

Zhang, UA PostDoc

Duck, UCSD PhD

Lostra, UA REU

Nema, UCSD PhD

Kuzuku, UA PhD

Shakya, UA PhD

Kuhlman, UA REU

Zhang, UA PhD

Nema, UCSD PhD
Student Participation
Specimen Construction/Instrumentation

Preparing Rubber Bearing Assemblies

Ulina
Mackenzie
Nelson
Arpit
Shake Table Testing Phase

Berkeley BE05 MCE
Traditional system vs IFAS

PLAN VIEW COMPARISON
Shake Table Testing Phase

Shake Table test
Rocking of Main(North) wall

PHASE I VS PHASE II
Shake Table Testing Phase

NEES@UCSD Shake Table Test Program: Inertial Force-Limiting Floor Anchorage Systems for Seismic Resistant Building Structures

The University of Arizona  
UC San Diego  
Lehigh University
Project Testing Phase

➢ Destructive Testing

![Graph showing white noise test case periods for different phases]

- Phase I
- Phase II
- Phase III

Day2 Day3 Day4 Day5 Day6 Day7 Day8

Period (s)

Days:
- Day 2: Reconnect ED
- Day 3: Install roller bearing
- Day 4: Weld PSA
- Day 5: Grout wall base
- Day 6: Reconnect ED
- Day 7: Install roller bearing
- Day 8: Weld PSA

NHERI @ UCSD Workshop, 14-15 December, 2015
Test Inspection

Shake Table Testing Phase
Unexpected Events

Shake Table Testing Phase
Project Testing Phase

- Public Relations and Marketing

PCI Shake Table Test Event
May 7 2007
Project Testing Phase

- Professional Interest and Collegiality
Specimen Demolition Phase

NEESR: Inertial Force-Limiting Floor Anchorage Systems for Seismic Resistant Building Structures

Site Cameras
- Southwest
- Northwest

NHERI @ UCSD Workshop, 14-15 December, 2015
Project Post-Test Phase

- Data Management
- Data Visualization / Manipulation
- Data Interpretation
- Data Archiving
- Model Calibration
- Findings and Conclusions
- Dissemination & Reporting
Data Interpretation

Project Post-Test Phase

Ground Motion

- Acceleration (g)
- Acceleration Along The Floors vs. Time (sec)
- Displacement Along Height vs. Length (ft)
- Displacement Relative to Foundation (in)

12.996
Model Calibration

Knoxville DBE

Diaphragm midspan roof drift
Data Interpretation

Project Post-Test Phase

Berkeley MCE IFAS25k Roller

Plan View floor 3

Plan View floor 4

Plan View floor 1

Plan View floor 2

IFAS North wall rocking

Traditional system North wall rocking

IFAS

NHERI @ UCSD Workshop, 14-15 December, 2015
Data Interpretation

North and West wall base in plane rotation

SE DBE

BE DBE

BE Svc

BE MCE

RotN

RotW

NHERI @ UCSD Workshop, 14-15 December, 2015
Data Interpretation

Berkeley BE05 MCE
ANSYS model with real time shake table test

ISOMETRIC VIEW – PHASE I
IFAS
Model Calibration

Project Post-Test Phase

Displacement (in.) vs. Time (s)

Floor 4

Floor 3

Floor 2

Floor 1

ANSYS

Test
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Thank You!

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