Workshop Agenda

Thursday
• 1:30pm Introductions
• 1:45pm Overview of NHERI@UTexas Equipment Facility
• 2:45pm Presentation by Dr. Woods
• 3:00pm Overview of EAGER project and bridge testing
• 4:00pm Presentations on NDE research from Rutgers faculty
• 4:30pm Travel to BEAST facility for tour
• Evening Dinner (pay for yourselves)

Friday
• 7:45am Meet in hotel lobby to take bus to bridge testing
• We plan to be back at the hotel before 11:30am
Large Mobile Shakers for Natural Hazard Field Studies to Develop Resilient and Sustainable Infrastructure (Award CMMI-1520808)

NHERI Experimental Facility, NHERI@UTexas

Principal Investigator:
Dr. Kenneth H. Stokoe, II, P.E., NAE
*UT Austin, Dept. of Civil, Architectural, and Environmental Engineering (CAEE)*

Co-Principal Investigators:
Dr. Brady R. Cox, P.E.
*UT Austin, CAEE*

Dr. Patricia Clayton
*UT Austin, CAEE*

August 3, 2017
NHERI@UTexas Technical Personnel

**Director/PI**
Kenneth Stokoe
Professor, UT Austin

**Co-PI**
Brady Cox
Assoc. Professor, UT Austin

**Co-PI**
Patricia Clayton
Asst. Professor, UT Austin

**Operations Manager**
Farnyuh Menq
UT Austin

**IT/Cybersecurity**
Robert Kent
UT Austin

**Hydraulics Technician**
Andrew Valentine
UT Austin

**Mobile Shaker Specialist**
Cecil Hoffpauir
UT Austin

**Senior Personnel**
Sharon Wood
Dean & Prof., UT Austin
NHERI@UTexas Facility

University of Texas at Austin Pickle Research Campus (PRC)

University of Texas at Austin Main Campus
NHERI@UTexas - Building 46

- 50 ft by 65 ft storage building of NHERI@UTexas
- NEES@UTexas mobile shakers
- 50 ft by 200 ft parking area available for NHERI@UTexas
- Ferguson Structural Engineering Laboratory

North
Building 46 Facility

12 ft * 12 ft garage doors

Indoor equipment storage, maintenance, and preparation area

Main entrance & Emergency Exit door

Air-conditioned office

Locked tool cage

50 PPT sensors

50 3D motion sensors

Fire Extinguishers

First aid kits & eye wash station

NHERI@UTexas

“The nation is our laboratory”
**Liquidator (Low Frequency Shaker)**
- Off-road buggy; weight = 72,000 lbs
- Two vibrational orientations
- Shear mode Peak Force = 20,000 lbs
- Vertical mode Peak Force = 20,000 lbs

**Raptor (Mid-Size Shaker)**
- Highway legal truck; weight = 41,200 lbs
- Vertical mode Peak Force = 27,000 lbs

**Rattler (Horizontal Shaker)**
- Off-road truck; weight = 54,500 lbs
- Shear mode Peak Force = 30,000 lbs

**Big-Rig**
- 26 wheeler tractor-trailer rig for shipping T-Rex, Liquidator, and Rattler

**T-Rex (Tri-axial Shaker)**
- Off-road buggy; weight = 64,000 lbs
- Three vibrational orientations
- Shear mode Peak Force = 30,000 lbs
- Vertical mode Peak Force = 60,000 lbs

**Thumper (Urban Shaker)**
- International 4300 truck; weight = 24,800 lbs
- Three vibrational orientations
- Shear mode Peak Force = 6,000 lbs
- Vertical mode Peak Force = 6,000 lbs

**Field-Support Truck**
- Carries diesel fuel for T-Rex and Liquidator
- Acts as a working platform for maintenance

**Instrumentation Van & Trailer**
- Cargo van with air-conditioned workspace
- Trailer with added work and storage spaces

**Hydraulic Cylinder with Adjustable Platform**
- Platform mounted at the rear of T-Rex
- Pushing and retrieving subsurface sensors
T-Rex

- Tri-axial shaker
- Push-button transformation of shaking orientation
- 32 ft long, 8 ft wide, Wt. = 64,000 lbs
- Only operating tri-axial vibroseis we are aware of in the world
T-Rex – Vertical Shaking
Liquidator

- Custom-built, one-of-a-kind, low frequency shaker
- Two-shaking orientations
- One-day shop transformation of shaking orientation
- 32 ft long, 8 ft wide, Wt. = 72,000 lbs
Liquidator – Standard Configuration
Liquidator – Special Configuration
Raptor

- Standard vibroseis, vertical shaker (P-wave)
- 32 ft long, 8 ft wide, Wt. = 41,200 lbs
Rattler

- Standard vibroseis, horizontal shaker (S-wave)
- 29 ft long, 8.5 ft wide, Wt. = 30,000 lbs
Thumper

- Mini-vibroseis/urban shaker
- Three vibrational orientations
- Two-hour field transformation of shaking orientation
- 27 ft long, 8.5 ft wide, Wt. = 28,400 lbs.
Big Rig

- 26-wheel tractor trailer for shipping T-Rex, Liquidator, and Rattler
Support Vehicles

Field/Fuel Truck

Instrumentation Van

Trailer #1 (with A/C)

Trailer #2

Provide fuel, storage, and workspace in the field
Instrumentation – Data Acquisition (DAQ)

72-channel VXI DAQ
- 24 bit digitizer
- Up to 50 kHz sampling rate
- Real-time frequency domain capabilities

136 channels of DAQ

64-channel Data Physics DAQ
- 24 bit digitizer
- Up to 200 kHz sampling rate
- Real-time frequency domain capabilities
Instrumentation – Sensors

1-Hz Geophones

109, 1-Hz Geophones
- 85 vertical & 24 horizontal
- 15,000 ft of cable

10, Nanometrics Broadband Seismometer Stations
- 3-component, GPS synchronized
- 120-sec period Trillium Compact seismometers
- Flat response 0.01 to 100 Hz
- Taurus digitizers (24 bits)
- Structural and Geotechnical applications
Instrumentation – CPT and Liquefaction Sensors

Cone Penetrometers
- Standard CPT
- Seismic CPT
- 4 different cones

Motion Sensors
- Tri-axial MEMS accelerometers
- 2D or 3D geophones

Liquefaction Sensors
- Custom built
- Pore water pressure transducers
Additional Instrumentation Resources

- IRIS/PASSCAL

Free to NSF-funded projects
*PI pays for shipping & travel expenses

- (35) 3D accelerometers
- Digitizers
- Field support
- and more...
“Have mobile shakers, will travel...”

Over 50 Projects 2003 - 2014 (NEES, Shared-use, Industry/Gov.)
1. Liq. Demo SAGEEP S. Carolina
2. Explore UT Austin Texas
3. Deep Downhole PNNL, WA
4. Hoodoos LANL N. Mexico
5. MSW Landfill Los Angeles
Thumper:

1. Vs Profile
Mauna Kea
Hawaii

2. Topo. Amp.
Deer Creek
Utah

3. Hispanic
Eng. Week
South TX

4. Geophysics
Sum. Camp
Colorado

5. Vs Profile
Stanford U.
California
Liquidator:

1. Deep Vs Yucca Mtn. Nevada
2. Deep Vs Mississippi Embayment
3. Deep Vs Salt Lake Valley Utah
4. Deep Vs Hanford PNNL, WA
5. Deep Vs Palo Verde NPP Arizona
Proof-of-Capability Workshops

- Each test aligned with one of three main areas in our Science Plan:
  
  (1) Subsurface Imaging (2D/3D)
    (St. Louis, MO; November 11, 2016)
  
  (2) In-situ Liquefaction/Nonlinear Testing
    (Portland, OR; June 24, 2016)
  
  (3) Structural Health Monitoring/SFSI
    (Brunswick, NJ; August 3-4, 2017)
Proof-of-Capability Workshops cont...

- Marketing to broaden the user base
  - Familiarize potential users with NHERI@UTexas capabilities
  - Invite all interested parties (Gov/Academia/Industry)
  - Data and metadata posted to NHERI DesignSafe-CI (open access)
  - Generate preliminary proposal data
  - Opportunities for piggy-back projects

Thumper at levee testing workshop

Liquefaction testing workshop
Science Plan #1:

Performing deeper, more accurate, higher resolution, 2D/3D subsurface geotechnical imaging

Retrieve:
- Shear Wave Velocity (Vs)
- P-wave Velocity (Vp)

for direct determination of elastic moduli needed in engineering analyses
NEES@UTexas Project Highlight


(CMMI-1303595)

Long-period GM’s not understood

4 September 2010

~ 80% of buildings in CBD demolished
Complex Subsurface Conditions & Deep Bedrock

- Geotechnical investigations do not extend past Riccarton Gravel layer (artesian aquifer) at 10 – 40 m
- Result: no detailed Vs profiles deeper than 40 m in Christchurch
- Deepest well in city ~ 450 m ... still no bedrock

(after Brown and Weeber 1992)

(after Brown 1998 and Barnes 2012)
T-Rex in Christchurch

- Shipped from Texas to Christchurch in Feb. 2013
Christchurch Surface Wave Testing Sites

- 15 primary sites in greater Christchurch
- Target depth of $V_s$ profiling: 400m – 1000m
- Approximately 2 days of testing per site
Combined Active-Source & Ambient-Wavefield Surface Wave Testing
Reliable 1D Vs Profiles to Record Depths

Inversion Process

- Analysis took weeks for each site
- Millions of models searched via Monte-Carlo/Neighborhood algorithms
- Hours of computer time followed by user scrutiny, model adjustment, repeat inversion

![Graph showing shear wave velocity profiles with depth and uncertainty quantification.](image-url)

- Max prior Vs depth
- Bedrock ~ 1 km
- Uncertainty Quantified

Sigma[ln(Vs)]

Lowest Misfit Profile
5% & 95% Profiles
"Best" 1000 Profiles
"Best" 50 Profiles
Science Plan #2:
Characterizing the nonlinear dynamic response and liquefaction resistance of complex geomaterials in situ

Determine nonlinear relationship between:
• Shear modulus and shear strain
• Constrained modulus and axial strain
• Pore water pressure generation and shear strain

for use in static (settlement) and dynamic (site response) engineering analyses
In-Situ Nonlinear Geotechnical Testing

Shallow In Situ Non-linear Testing of Liquefiable Soils
NEES@UTexas  Project Highlight

“Field Investigation of Shallow Ground Improvement Methods for Inhibiting Liquefaction Triggering; Christchurch, New Zealand”

(CMMI-1343524)
NZ EQC Ground Improvement Trials

Objective: Rebuild Christchurch with Affordable Resilience

- **Rapid Impact Compaction (RIC)**
- **Rammed Aggregate Piers (RAP)**
- **Low Mobility Grout (LMG)**

Techniques for “green” sites or demolished home sites
In-Situ Liquefaction Testing with T-Rex

a. Cross-sectional perspective of T-Rex in place to shake the RAP.

b. Plan view of central portion of RAP test panel
Ground Improvement Trials Video
Science Plan #3: Developing rapid, in-situ methods for non-destructive structural evaluation and soil-foundation-structure interaction (SFSI) studies

3 methods of structural testing with NHERI@UTexas equipment:
(1) Shaking ground around a structure
(2) Shake the structure directly
(3) Quasi-static pullover
Structural Testing

• In the lab...

Hybrid testing at Lehigh

Shake table testing at UC San Diego

• In the field...

Complex soil conditions

Corrosion

Scour

Degradation (below ground/water)
NEES@UTexas Project Highlight
“Collaborative Research: Demonstration of NEES for Studying Soil-Foundation-Structure Interaction”
(CMMI-0324326)
Typical Structures

Fundamental frequency range for:
- Typical bridges
- Low-rise reinforced concrete and steel buildings
- Wood residential buildings
- Large-scale specimens

Horizontal force output
Other Examples


Modal testing using small vibroseis, similar to Thumper
Additional Instrumentation Resources

- IRIS/PASSCAL
- User-provided

Wireless Sensors for Structural Health Monitoring

Instrumentation from user’s home institution (e.g., LVDTs, inclinometers, strain gages, etc.)
NSF proposals

- Submission windows
  - January 10-24
  - September 1-15
- Can use NHERI equipment in proposals to any NSF program
Example of Estimated Costs Associated with Using the NHERI@UTexas Equipment Facility on NSF-Funded Research Projects

<table>
<thead>
<tr>
<th>Step 1: Estimated total time needed for the testing</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated time required for testing</td>
<td>30</td>
</tr>
<tr>
<td>Realistic estimation of required time</td>
<td>60</td>
</tr>
<tr>
<td>Total days of testing</td>
<td>10</td>
</tr>
<tr>
<td>Travel</td>
<td>4</td>
</tr>
<tr>
<td>Weekends</td>
<td>2</td>
</tr>
<tr>
<td>Days in the field</td>
<td>16</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Step 2: Estimated equipment costs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T-Rex</td>
<td>$1,620</td>
</tr>
<tr>
<td>Vibrator</td>
<td>$1,620</td>
</tr>
<tr>
<td>Tractor-Trailer</td>
<td>$4,260</td>
</tr>
<tr>
<td>Highway</td>
<td>$4,260    (fuel cost only)</td>
</tr>
<tr>
<td>Highway</td>
<td>$4,260    (fuel cost only)</td>
</tr>
<tr>
<td>Recording equipment</td>
<td>$0</td>
</tr>
<tr>
<td>Instrumentation trailer</td>
<td>$0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 3: Estimated travel</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel</td>
<td>$7,000</td>
</tr>
<tr>
<td>Plane tickets</td>
<td>$500</td>
</tr>
<tr>
<td>Rental van</td>
<td>$500</td>
</tr>
<tr>
<td>Breakdown induced travel*</td>
<td>$200</td>
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<tr>
<td>Total Travel</td>
<td>$7,000</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 4: Estimated other cost</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Material and supply</td>
<td>$500</td>
</tr>
<tr>
<td>Mobile phone service in the field</td>
<td>$500</td>
</tr>
<tr>
<td>Site liability insurance**</td>
<td>$500</td>
</tr>
<tr>
<td>Total Others</td>
<td>$500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 5: Estimated total cost</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Direct cost</td>
<td>$14,280</td>
</tr>
<tr>
<td>Indirect cost (55% overhead)</td>
<td>$7,854</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$22,134</td>
</tr>
</tbody>
</table>

Budget worksheet posted on DesignSafe

NSF user pays only for fuel for truck(s), truck shipment, and personnel travel

$22,134 (for this example)
Example of Estimated Costs Associated with Using the NHERI@UTexas Equipment Facility on non-NSF-Funded Research Projects

<table>
<thead>
<tr>
<th>Step 1: Estimated total time needed for the testing</th>
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<tbody>
<tr>
<td>Estimated time required for testing: 30 hours</td>
</tr>
<tr>
<td>Realistic estimation of required time: 60 hours</td>
</tr>
<tr>
<td>Total days of testing: 10 days</td>
</tr>
<tr>
<td>Travel: 4 days</td>
</tr>
<tr>
<td>Weekends: 2 days</td>
</tr>
<tr>
<td>Days in the field: 16 days</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 2: Estimated equipment costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-Rex</td>
</tr>
<tr>
<td>Vibratlon (Big Rig)</td>
</tr>
<tr>
<td>Highway</td>
</tr>
<tr>
<td>Fuel-Supply Pickup Truck</td>
</tr>
<tr>
<td>Recording equipment</td>
</tr>
<tr>
<td>Instrumentation Trailer</td>
</tr>
<tr>
<td>Total Equipment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 3: Estimated travel costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Travel</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 4: Estimated other costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material and supply</td>
</tr>
<tr>
<td>Mobile phone service in the field</td>
</tr>
<tr>
<td>Site liability insurance**</td>
</tr>
<tr>
<td>Total Others</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 5: Estimate of personnel cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Technicians</td>
</tr>
<tr>
<td>1 Engineer</td>
</tr>
<tr>
<td>Total Personnel</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step 6: Estimated total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total direct cost</td>
</tr>
<tr>
<td>Indirect cost (55% overhead)</td>
</tr>
<tr>
<td>Total Cost</td>
</tr>
</tbody>
</table>

Non-NSF user pays for truck fuel and shipment, personnel travel & overtime + equipment usage fees

Budget worksheet posted on DesignSafe

$144,834 (6.5x more for this example)
Additional Information & Proposal Help

- Dr. Kenneth Stokoe (PI) k.stokoe@mail.utexas.edu
- Dr. Brady Cox (co-PI) brcox@utexas.edu
- Dr. Patricia Clayton (co-PI) clayton@utexas.edu
- Dr. Farnyuh Menq (Operations Manager) fymenq@utexas.edu

- NHERI@UTexas website at www.designsafe-ci.org
  – Webinar slides & budgetary info is posted