NEES@UCLA: Field Testing for Structural and Geotechnical Research

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NEES@UCLA

GeoFrontiers05 1/24/2005
Acknowledgements

Support for NEES@UCLA is from the National Science Foundation as part of the George E. Brown Jr. Network for Earthquake Engineering Simulation

Principal Investigators during construction phase were:
- John Wallace
- Jon Stewart
- Patrick Fox
- Joel Conte
- Deborah Estrin
Concept: Advanced Dynamic Field Testing of Civil Structures
NEES@UCLA Equipment

EQUIPMENT
- 3 large mobile shakers
- Extensive field-deployable monitoring instrumentation system
- CPT truck for research use

USES
- Large-amplitude excitation of structures
- Field testing/temporary monitoring of structures
- Site characterization and installation of subsurface sensors using CPT
Large unidirectional eccentric mass shaker

Qty: 2
Freq: 0-25Hz
Force: 100kip each
Omnidirectional Eccentric Mass Shaker

Qty: 1
Freq: 0-4Hz
Force: 15kip
15kip Linear Hydraulic Shaker

Qty: 1
Freq: 0-20Hz
Force: 15kip
Waveform: Arbitrary, digitally-controlled force or displacement
Mobile Command Center

- Self-Contained Panel Truck
- Generator power
- Satellite Uplink
  - 1.8m dish
  - T1 speed
- WiFi/LAN Hardware
- NEESpop
- Data and analysis computers
Wireless Network

- Data Concentrator
- Sensor stations
- Access points
- Workgroup
- Wireless Backbone

Wireless Network components include:
- Data Concentrator
- Sensor stations
- Access points
- Workgroup
- Wireless Backbone
CPT Truck

- Vendor: Hogentogler, Inc.
- Site characterization
  - Tip resistance
  - Sleeve resistance
  - Inclination
  - Pore pressure
  - Geophone for downhole shear wave velocity
Retrievable Subsurface Accelerometer

- Insert with CPT truck
- Compatible with Q330 data loggers
- Retrievable with winch
- Silicon Designs MEMS triaxial accelerometer
- Downhole signal conditioning to reduce noise contamination
- Micro-controller for built in sensor intelligence
RSA Installation
Project Example: Four Seasons

- "Four Seasons" building
  - Four-story with penthouse
  - Reinforced Concrete building

- Structural system
  - Lateral Load:
    - Perimeter ductile moment resisting frame
  - Gravity Load:
    - Post-tensioned flat slab + interior column
Building Description

- Damage by Earthquake
  - Northridge earthquake (Jan. 14, 1994)
  - Punching shear failure at interior floor slab - column connection
  - Diagonal cracks perimeter frame
  - The building was “red-tagged” since the earthquake
Excitation: nees@UCLA Shakers

- Eccentric Mass Shakers (two on roof)

- Linear Shaker
  - Arbitrary forces; sine-sweep, white noise, earthquake-type loading
Instrumentation

- Accelerometers (100 ch)
- Strain Gauges (96 ch)
- DCDT (drift, 20 ch)

- Payload projects
  - Nonstructural (UCI)
  - Advanced sensors (CENS/UCLA)
## Four Seasons System ID Results

<table>
<thead>
<tr>
<th>Modes that Dominate in E-W Direction</th>
<th>Mode No.</th>
<th>1st</th>
<th>2nd</th>
<th>4th</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency (Hz)</td>
<td>0.89</td>
<td>2.73</td>
<td>5.57</td>
<td>8.61</td>
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<tr>
<td></td>
<td>Damping (%)</td>
<td>0.05</td>
<td>0.04</td>
<td>0.06</td>
<td>0.03</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Modes that Dominate in N-S Direction</th>
<th>Mode No.</th>
<th>1st</th>
<th>2nd</th>
<th>4th</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency (Hz)</td>
<td>1.01</td>
<td>3.04</td>
<td>5.94</td>
<td>9.65</td>
</tr>
<tr>
<td></td>
<td>Damping (%)</td>
<td>0.05</td>
<td>0.06</td>
<td>0.08</td>
<td>0.05</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Modes that Dominate in Torsion</th>
<th>Mode No.</th>
<th>1st</th>
<th>2nd</th>
<th>4th</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency (Hz)</td>
<td>1.34</td>
<td>3.53</td>
<td>6.46</td>
</tr>
<tr>
<td></td>
<td>Damping (%)</td>
<td>0.06</td>
<td>0.06</td>
<td>0.07</td>
</tr>
</tbody>
</table>
Initial Geotechnical Projects

- NEES@UCSD foundation vibration attenuation study
- NEES-IRIS wave propagation study at Garner Valley
- Upcoming NEESR project: BYU dynamic + static foundation impedance study
- ANSS sensor tests
Opportunities

- NEES@UCLA facilities and personnel are available to the research and practice community for field testing

Opportunities for use include:
- Building/Bridge/Dam structural response and performance studies
- Health monitoring and sensor network studies
- Response and performance studies for geo-structures and soil deposits
- Soil-Structure Interaction Studies
SSI Research Using NEES@UCLA

**Issues:**
- Foundation impedance of full-scale structures is still poorly defined
- Linear (small-strain) measurements often poorly correlated with measured soil properties
- Linear/Nonlinear strain field not well understood
- Damping (hysteretic and radiation) not well understood

**NEES@UCLA Opportunities:**
- Full-scale dynamic testing of actual or model structures with extensive above-ground and foundation instrumentation
- Add below-ground sensors (i.e RSA’s) for wave propagation and strain field measurements
- Use NEES IT capabilities for remote participation and collaboration
For Further Information

- www.nees.org
- nees.ucla.edu
- nigbor@ucla.edu
NEES@UCSB

• 3D Geotechnical Arrays at 2 permanent field sites in Southern California
• Soil-Foundation-Structure-Interaction (SFSI) Test Structure

➢ Real earthquake data for pure & applied research
➢ Test bed for geotechnical and geophysical methods
➢ Location for active experiments in a well-characterized field setting

nees.ucsb.edu
Location of Garner Valley Digital Array (GVDA) and Wildlife Array (WLA)
GVDA Permanent Array

M2.2 August 22, 1995-14km hypocentral distance

Acceleration (cm/s²) data from 0-10 Hz

Acceleration (cm/s²) data from 0-40 Hz
SFSI Test Structure at GVDA

- 4mx4mx4m
- 35 tons
- Structural stiffness ~ soil stiffness
- Configurable bracing to modify stiffness
- Can add mass at roof
- 10 Hz fixed-base frequency without bracing, 15Hz with
- Can bolt large shakers from UCLA to roof
SFSI Structure Testing

F1: Permanent Shaker
F2: NEES@UCLA Shaker
F3: NEES@UTexas Shaker
F4: Natural Earthquake
Instrumentation

- Uni-axial Accelerometer
- Tri-axial Accelerometer
- Rotation Sensor
- Displacement Transducer
- Pressure Cell and Sensor
Measured Properties

Free Response, Y-Direction,
First Mode (9.77 Hz), Damping = 4.2%