Use of the NHERI Facility for Large-Scale Geotechnical Testing

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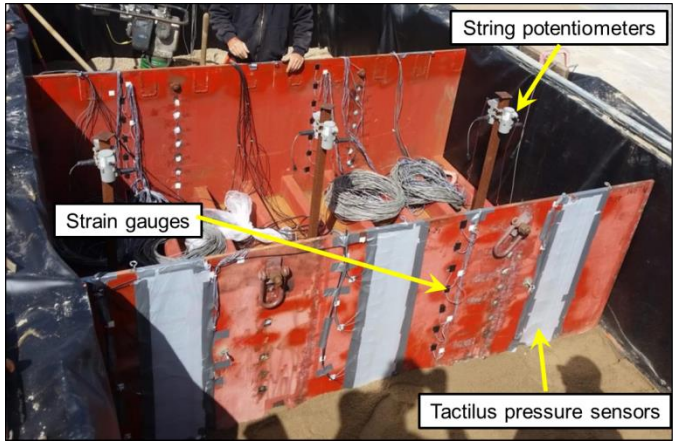
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

NSF

Outline

- **Utilizing Laminar Soil Container,**
  - Geotechnical Testing Projects
  - Test Model Construction (Time-Lapse Video)
  - Test Schedule on Shake Table
  - Instrumentation
  - Identification of Soil Properties
  - Shake Table Test Video
  - Recent Liquefaction Shake Table Test (on-campus)
- **Large Soil Confinement Box (LSCB) Testing**
- **Recommendations for Test**



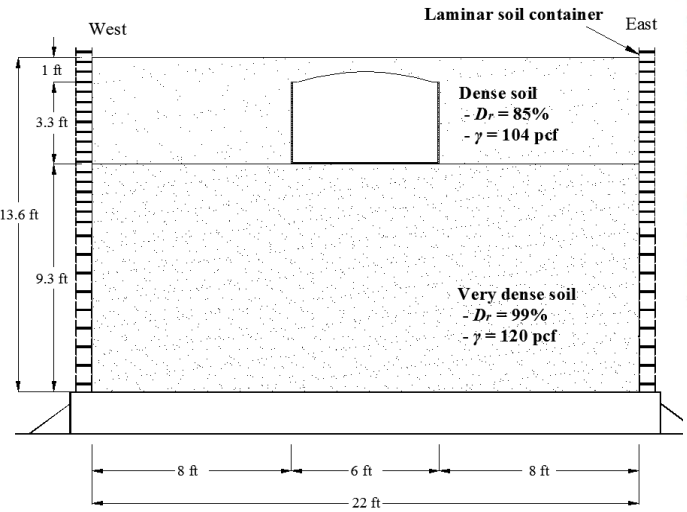
Large-Scale Laminar Soil Container

Laminar Weight to Soil Weight Ratio (target)	8 — 15%
Length to Height Ratio	L/H < 2.0
Width to Height Ratio	W/H < 1.0
Deflection Due to Soil-Water (2000 kg/m^3)	L/1000
Ratio of Frequency of Lateral Support (f_{lat}) to Interested Maximum Frequency (f_{max})	f_{lat}/f_{max} > 2.5
Ratio of Out-of-Plan Acceleration to Maximum Horizontal Acceleration	0.1 — 0.25
Ratio of Maximum Vertical Acceleration to Maximum Horizontal Acceleration	0.5 — 0.67
Laminar Frame to Soil Weight Ratio / Lateral Support to Soil Weight Ratio	< 0.1

http://nheri.ucsd.edu/facilities/soil-shear-box.shtml

❑ Phase II: Seismic Assessment of Cut-and-Cover Tunnel (2015-2016)

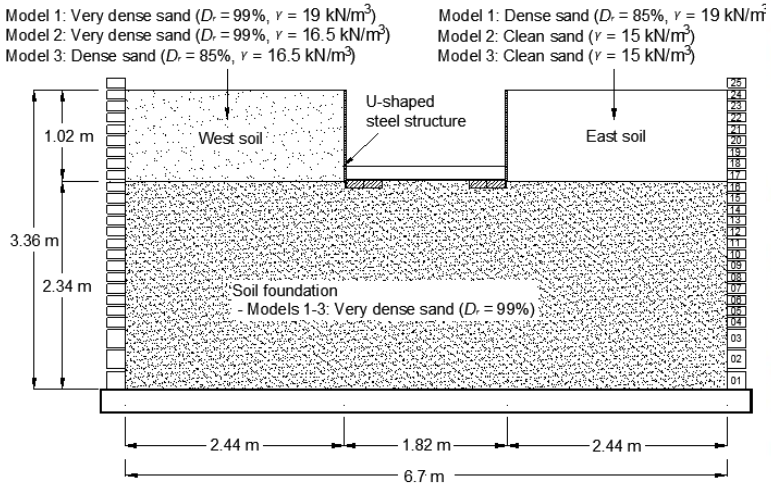
- Agent: California Department of Transportation (Caltrans)
  - Objective: Assessment of seismic response of ground tunnel system under different backfill conditions, burial depth, and earthquake excitation



❑ Spillway Retaining Wall Shake Table Test Program (2016-2017)

- ➢ Agent: Bureau of Reclamation (Denver, CO)

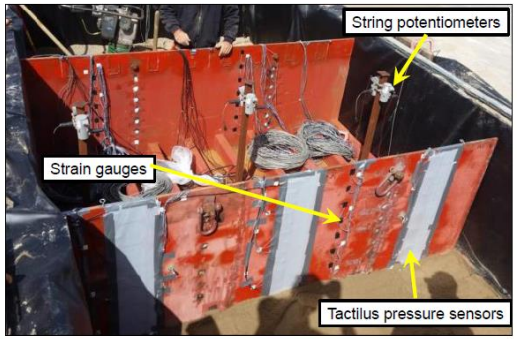
- Objectives: Assessment of seismic lateral earth pressure on a U-shaped structure under different conditions of backfill materials including cohesion effects and compaction/in-place density effects



(a) Laminar soil container base

(b) Assemblage of laminar soil container

(c) Backfill compaction



(d) U-shape structure instrumentation

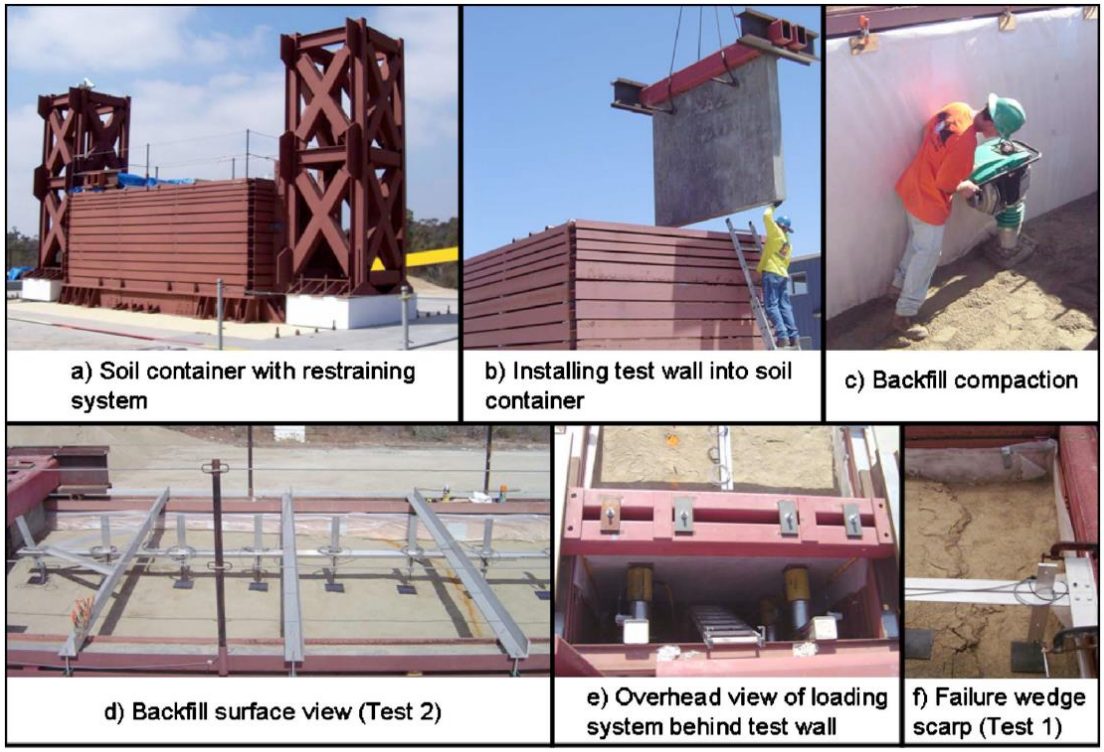
(e) Sand cone test

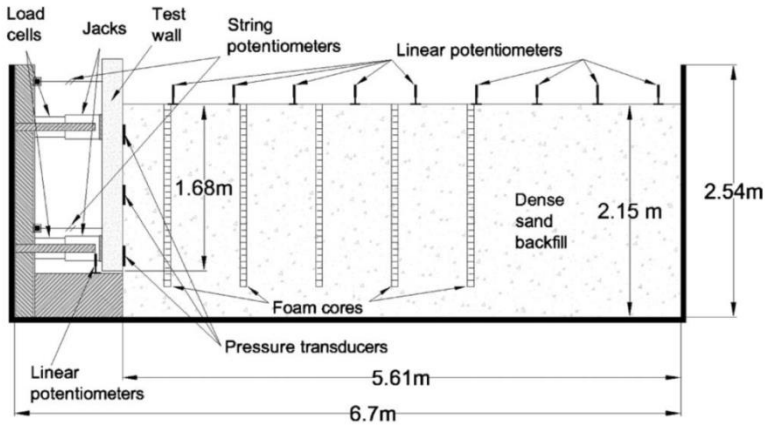
(f) Replacement of backfill

Geotechnical Testing Project III

❑ Large-Scale Passive Earth Pressure Load-Displacement Tests (2007)

- Agent: National Science Foundation (NSF)
- Objective: Assessment of passive earth pressure behind a retaining wall under lateral static loading

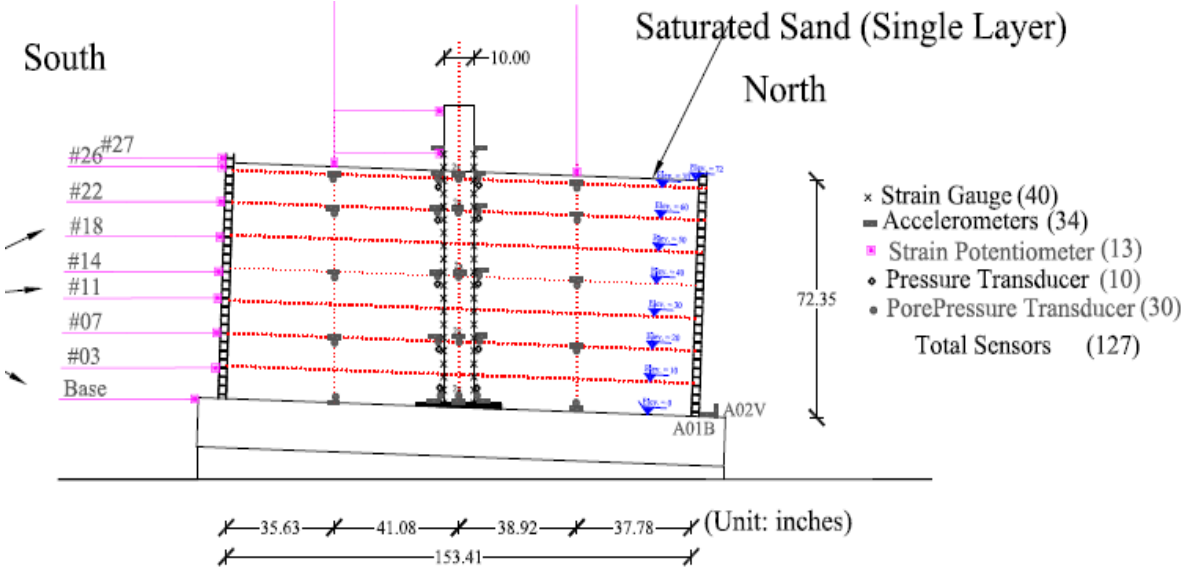


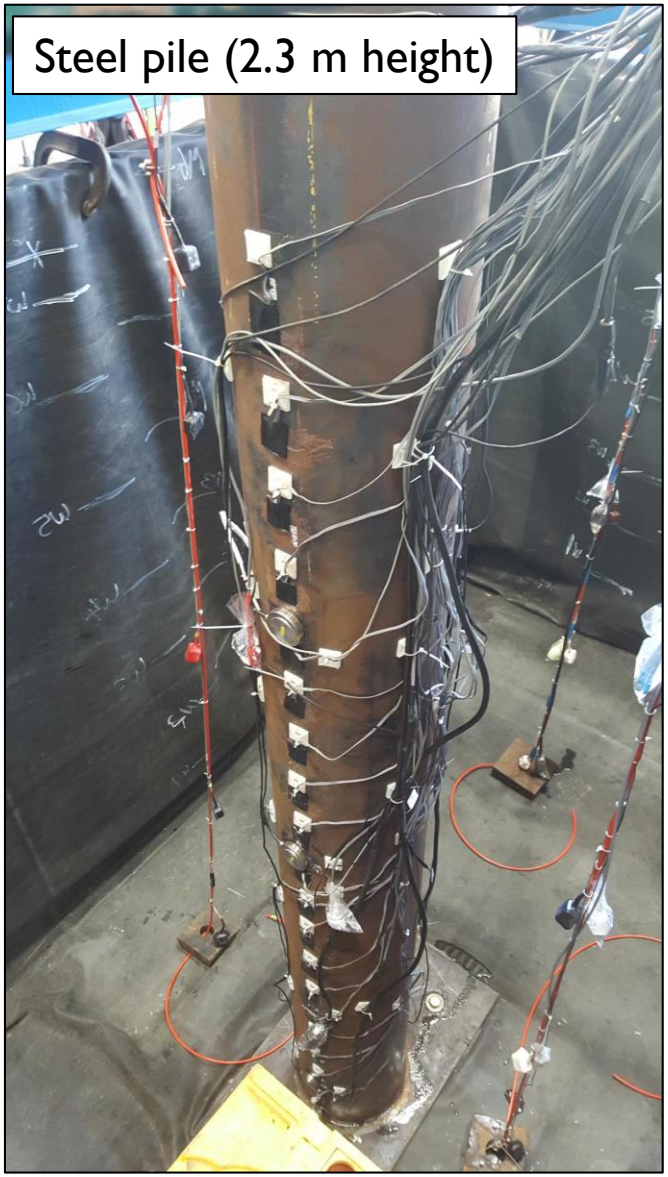


Wilson, P. and Elgamal, A. (2010) "Large-Scale passive earth pressure load-displacement tests and numerical simulation," Journal of Geotechnical and Geoenvironmental Engineering 136(12), 1634.

Liquefaction Shake Table Test (Powell Lab on Campus)

- Effect of Liquefaction-induced lateral spreading on pile foundation (Caltrans, 2017)





Liquefaction Shake Table Test (Powell Lab on Campus)

- Effect of Liquefaction-induced lateral spreading on pile foundation (Caltrans, 2017)

Construction of Large-Scale Geotechnical Test Model

Sequence of Test Model Construction

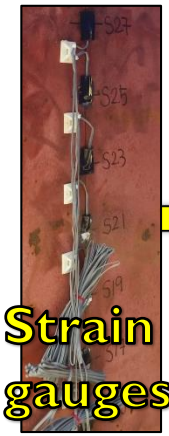
Test Schedule on Shake Table

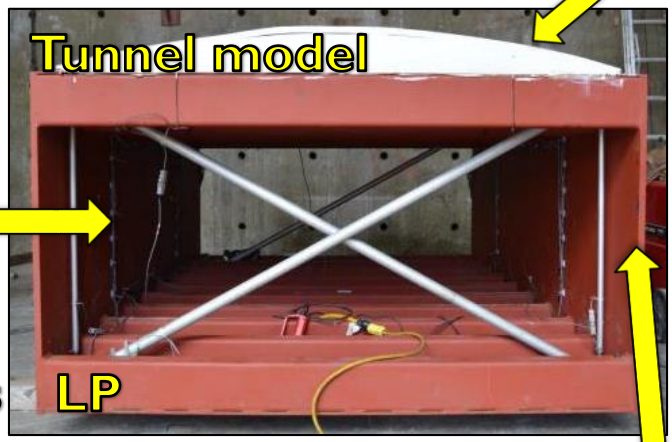
➢ **10 weeks total on the shake table (Caltrans tunnel project)**

Test	Task	Duration
1	1) Transporting laminar container base and frames	**6 weeks** after placing the container base
	2) Stacking laminar frames up to 9 ft height	
	3) Placing a plastic liner inside the container	
	4) Filling the container up to 9 ft height	
	5) Placing the tunnel	
	6) Filling the container up to 15 ft height	
	7) Instrumentation	
	8) 1st shake table test	Performed on 1/11/2016
2	1) Excavating 2 ft depth backfill	**3 days** after 1st test
	2) 2nd shake table test	Performed on 1/14/2016
3	1) Excavating 3.3 ft depth backfill	**2 weeks** after 2nd test
	2) Filling 4.3 ft height backfill	
	3) Instrumentation	
	4) 3rd shake table test	Performed on 1/26/2017
	Demolishing test model off the shake table	**1 week**

Instrumentation Plan

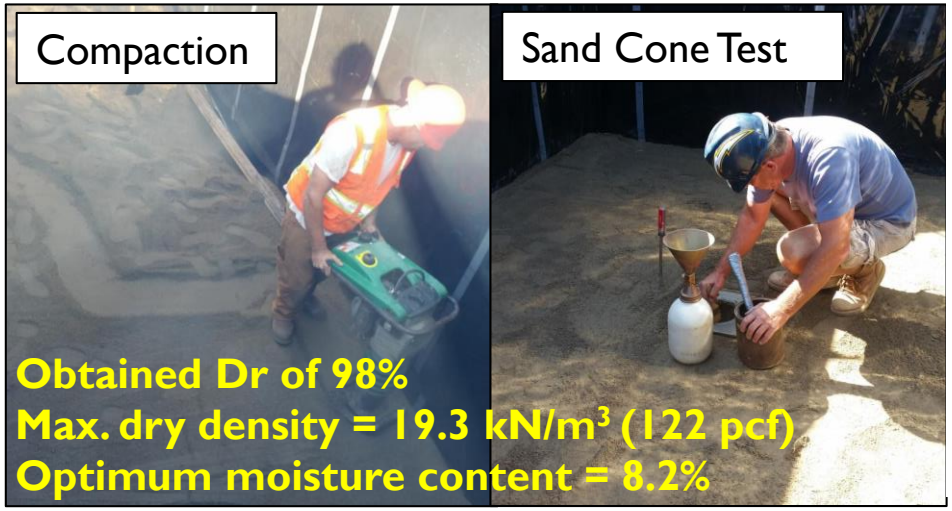
- A total of instruments = 205
  - Accelerometers
  - String potentiometers (SP)
  - Linear potentiometers (LP)
  - Strain gauges
  - Pressure sensors



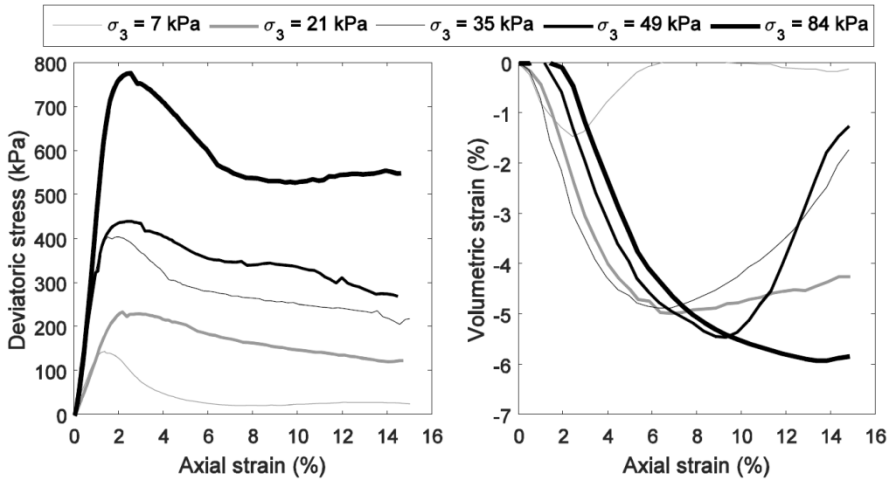


Identification of Soil Properties

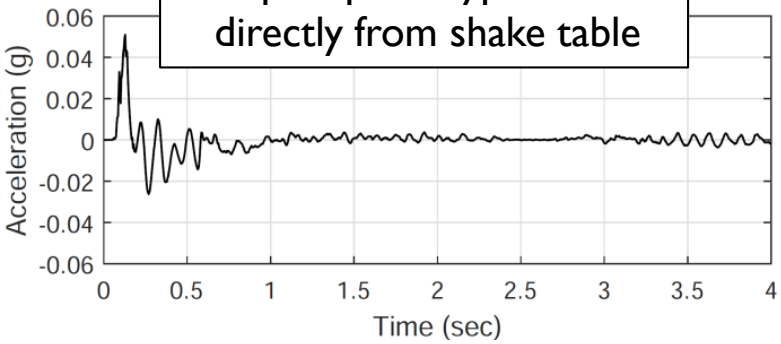
➢ Measurement of Relative Compaction

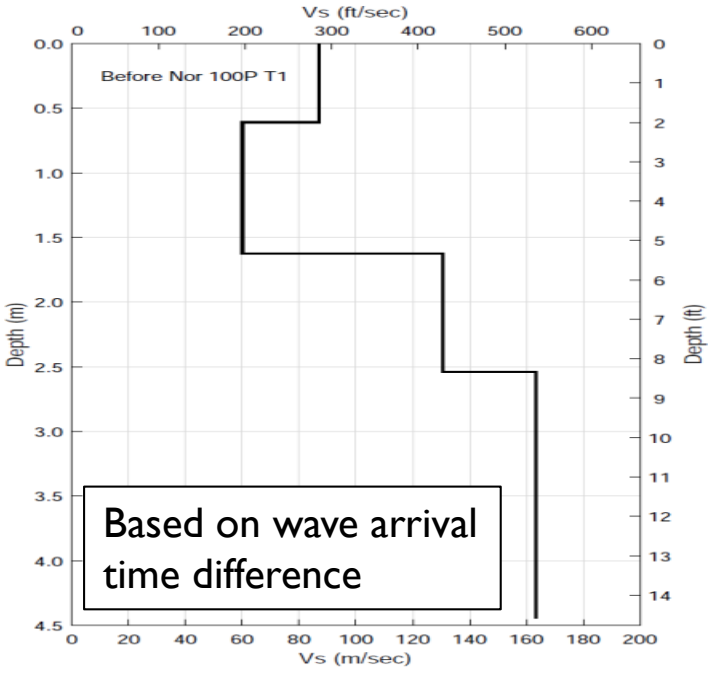


➢ Lab Triaxial Test



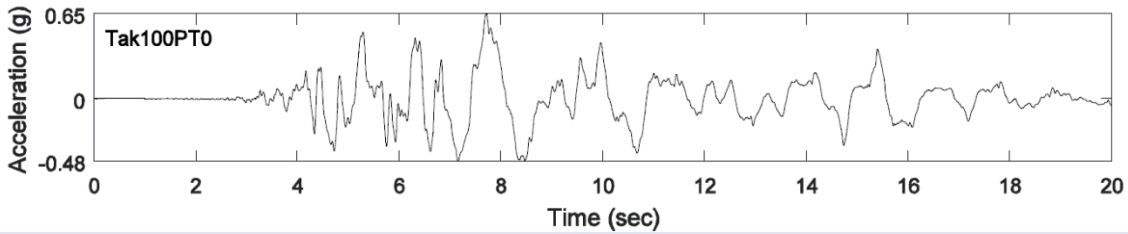
➢ Measurement of Shear Wave Velocity





Shake Table Test Video

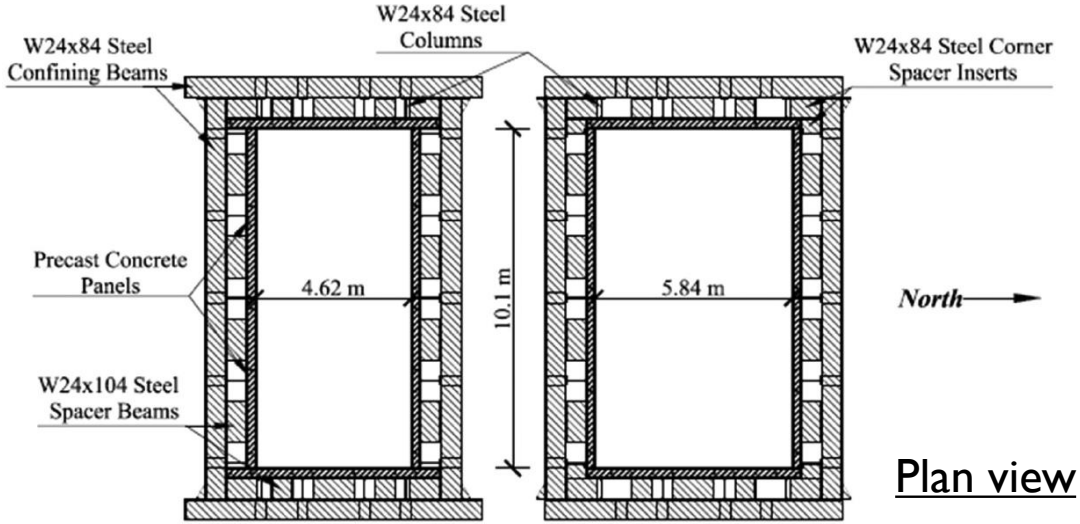
- Seismic Assessment of Cut-and-Cover Tunnel (Phase II)
  - Input motion : Takatori EQ (Tak100PT0) / Backfill compacted at D_r = 98%, 2 ft soil cover



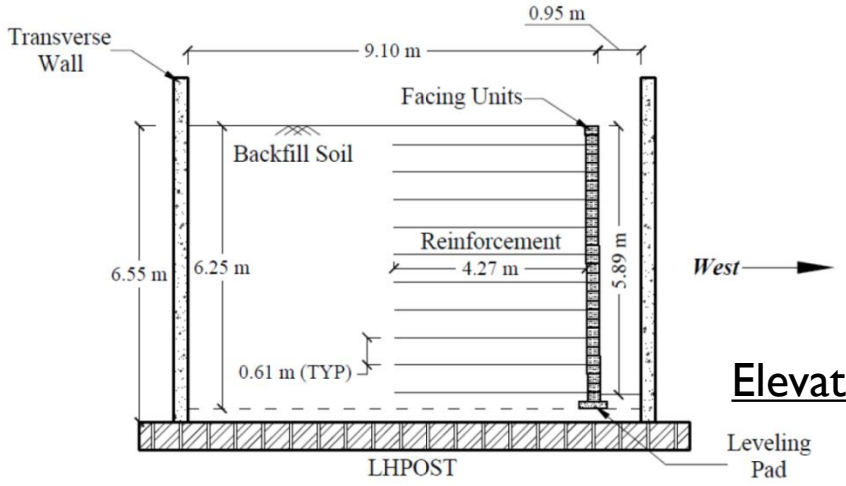
Shake Table Record
PGA of 0.65 g

Large Soil Confinement Box (LSCB) Testing

- Earthquake performance of Mechanically Stabilized Earth (MSE) walls



Plan view



Elevation view

Fox, P. J., Sander, A. C., Elgamal, A., Greco, P., Isaacs, D., Stone, M., and Wong, S., 2014. Large soil confinement box for seismic performance testing of geo-structures, Geotechnical Testing Journal 38, 72–84.

❑ Key parameters to succeed large-scale geotechnical testing

➢ Identification of backfill material properties

- Shear wave velocity, in-place soil density, relative compaction,…
- Understanding/monitoring of variability of achieved ground properties during sequence of shaking events

➢ Preparation of reliable and in-advance instrumentation plan

- Invisible are the most important sensors to measure dynamic response of soil and buried part of a structure → challenge of sensor replacement for large-scale test setup
- Early instrumentation effort is needed during the construction (avoid unnecessary time delay)
- The better prediction from pre-numerical simulation effort, the more accurate instruments available (data resolution for relatively low level of disp., earth pressure…)

➢ Minimizing friction mechanism of laminar frames

- Lubricating laminar frames and sliding rings
- Placing flexible but durable plastic liner inside the box

➢ Protection of test model (soil)

- Check daily on-site weather
- Unlike RC or steel structure, soil test model is vulnerable to rain or dew from temperature change day and night (we are in California) during the entire test process (e.g. construction, before/after shaking tests, and rebuilding the next model)

Thank You !!