

University of Nevada, Reno

Large-Scale Shake Table Validation of Kinematic SSI Transfer Functions for Deeply Embedded Foundations: A Blind Prediction Study

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- Los Alamos National Laboratory
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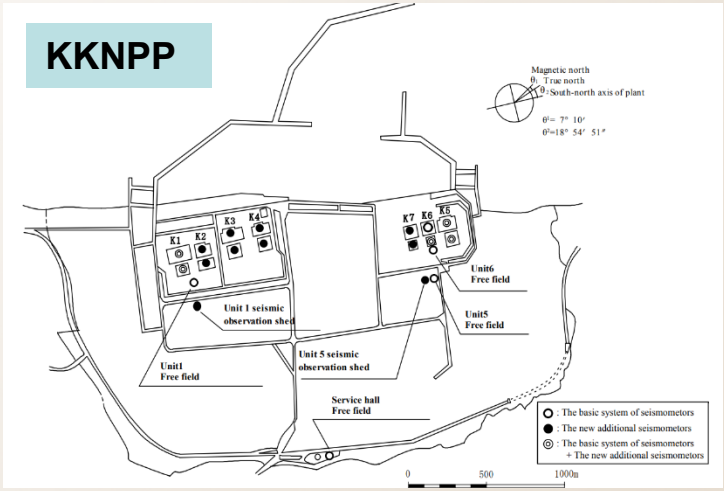


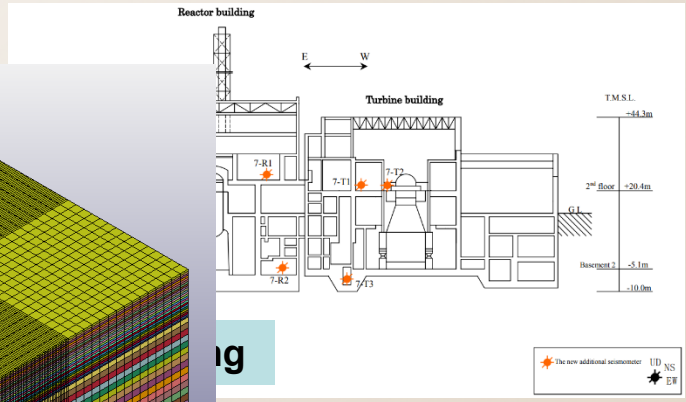
Presentation Outline

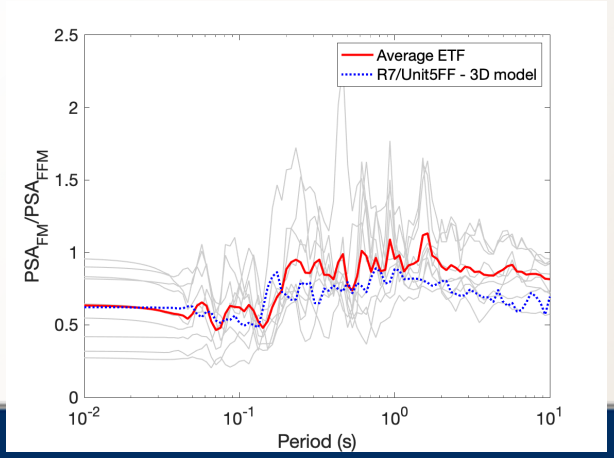
- Background and motivation
- Classes of blind predictions
- Shake table testing program
- Prediction results and main observations
- Overall assessment

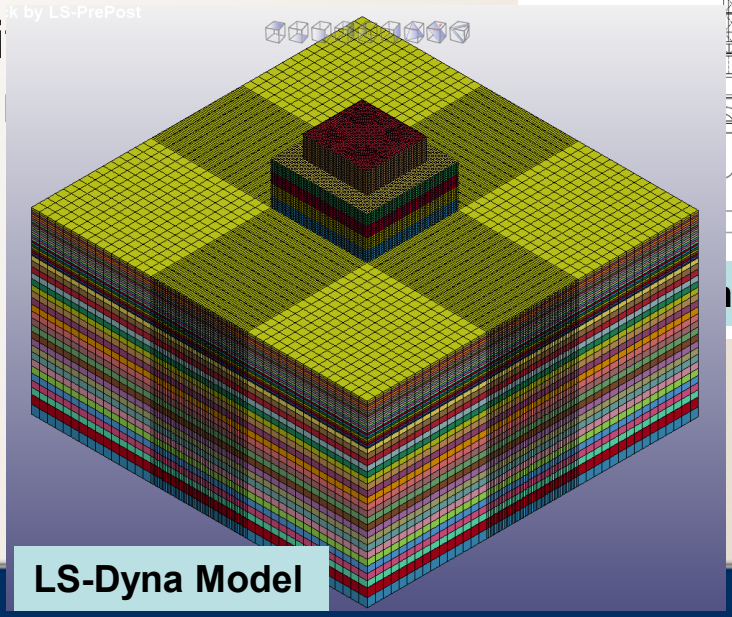
Predictions in Geotechnical Earthquake Engineering

- Essential to examine and classify predicted performances against measured values
- A prediction is a forecast using some method, an integral component in civil engineering
- Geotechnical engineering practice heavily relies on predictions towards design => cri
  safety, functionality, a









Classes of Predictions in Geotechnical Engineering (Lambe, 1973 — 13th Rankine Lecture)

- Lambe (1973) introduced a systematic classification of predictions based on two criteria: (1) when the prediction is made relative to the event, and (2) whether the outcome is known at the time the prediction is made
- To explain discrepancies and evaluate various prediction techniques, indicating limitations and reliabilities
- Example performance criteria include deformations, loads, accelerations, etc
- Highly variable sc
  spatial) => widely
- Five classes of pr

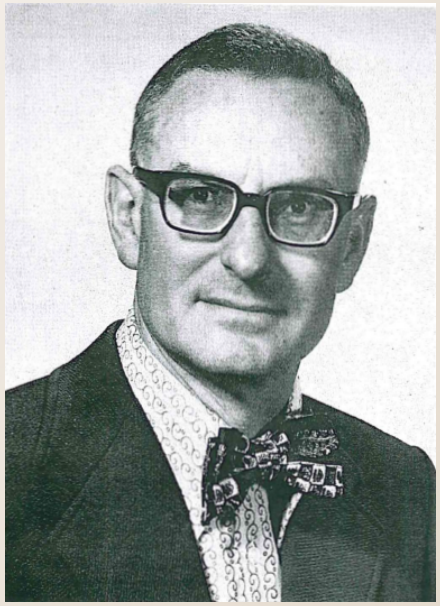


Photo source:
V. Lamb (1973), Geotechnique

Prediction type	When prediction made	Results at time prediction made
A	Before event	-
B	During event	Not known
B1	During event	Known
C	After event	Not known
C1	After event	known

Types of Blind Predictions

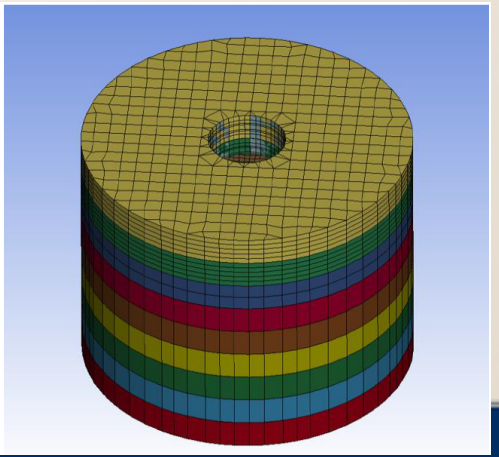
- Numerical simulations can be used to predict the response of geotechnical structures to future loading scenarios such as seismic events (e.g. design earthquakes) and are an essential part of geotechnical engineering practice
- Predictions of geo-structure experiments can be categorized into Class A, B, and **C**
- Class A predictions are the most challenging and most valued — made blindly, before any results are available
- Class C1 predictions, while made after the event, remain meaningful when the predictor has no access to outcome data during model development in the context of a blind prediction competition

Blind Prediction Framework Applied to Kinematic SSI Testing

- This study employs both Class A and Class C1 predictions for kinematic SSI response of a deeply embedded foundation tested on the UNR shake table
- Class A: Numerical simulations in LS-Dyna were completed prior to testing, using only target input motions and assumed soil properties — no experimental response data available
- Class C1: Simulations subsequently repeated using measured shake table motions as input and updated soil properties, while retaining identical modeling assumptions
- Focused on free-field and foundation motion responses as evaluation criteria

Newly commissioned laminar soil box on a biaxial shake table at UNR

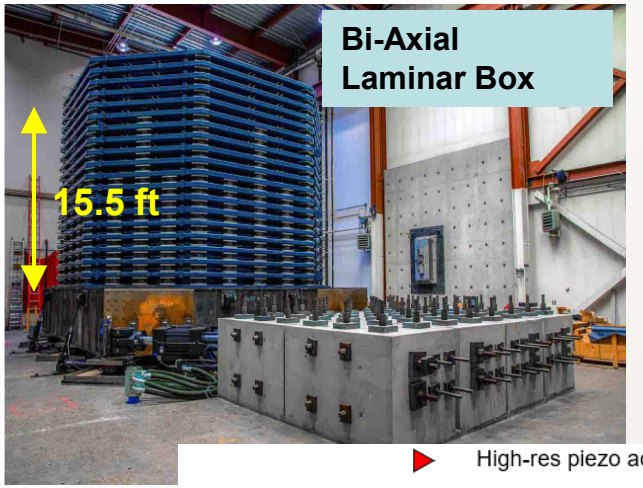




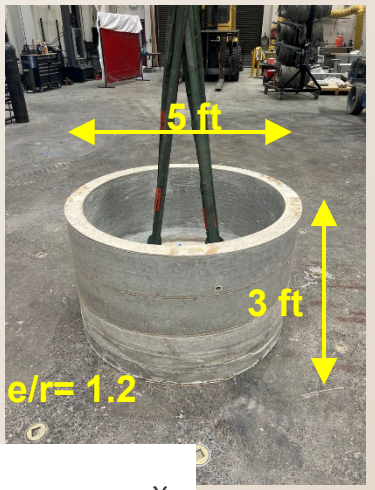
LS-Dyna model

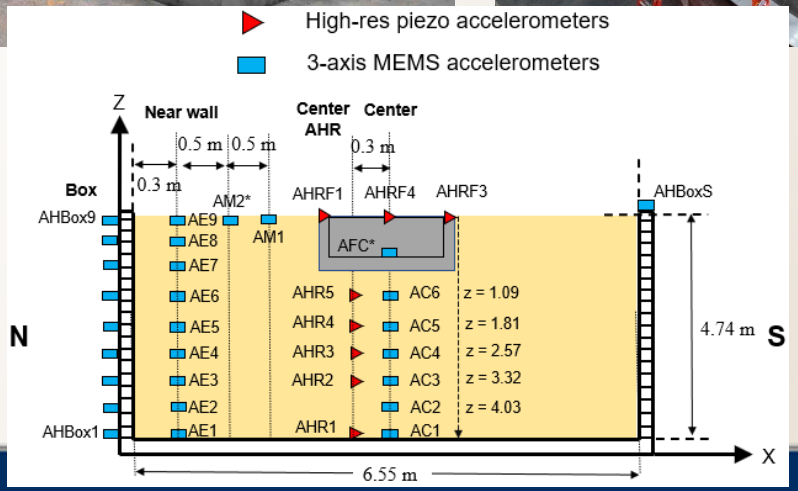
Large-Scale Shake Table Testing Program

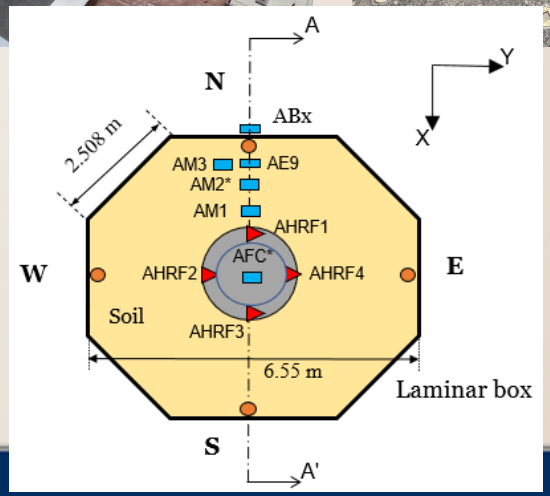
- A comprehensive series of large-scale shake table tests were conducted at the Earthquake Engineering Laboratory, UNR
- Experimental layout was inspired by the Lotung site (scale: 1/7)







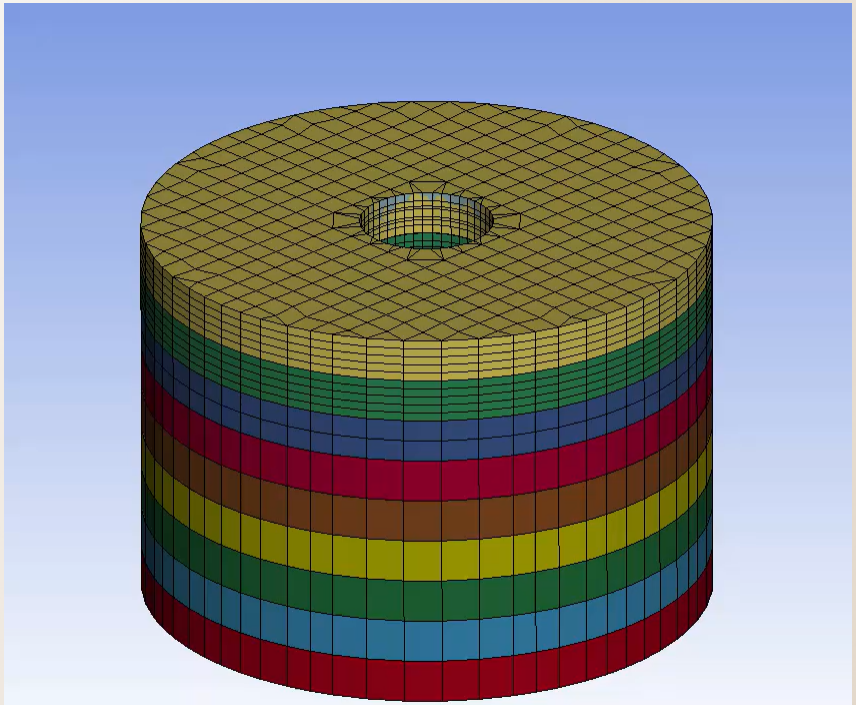




LS-Dyna Modeling (1/2)

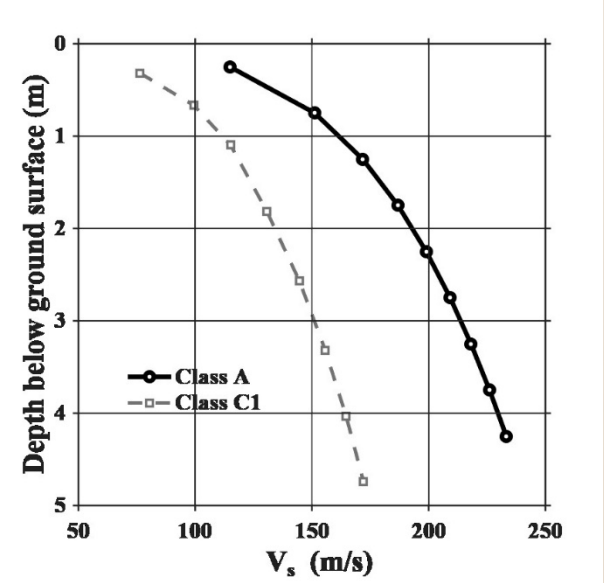
- 3D FE numerical domain included model ground specimen and embedded foundation
- Prescribed model geometry, soil properties, foundation configuration, boundary conditions, damping formulation, and input motions (in Class A blind prediction) => informed selection of input motions for the experiments
- Soil was discretized using 3D solid elements, with vertical layering selected to represent the stress-dependent variation of soil properties with depth
- Foundation was modeled as a rigid embedded circular foundation
- Soil-foundation interface was represented using tied contact
- Boundary conditions: to reproduce the shear-beam response of the laminar soil box during horizontal shaking

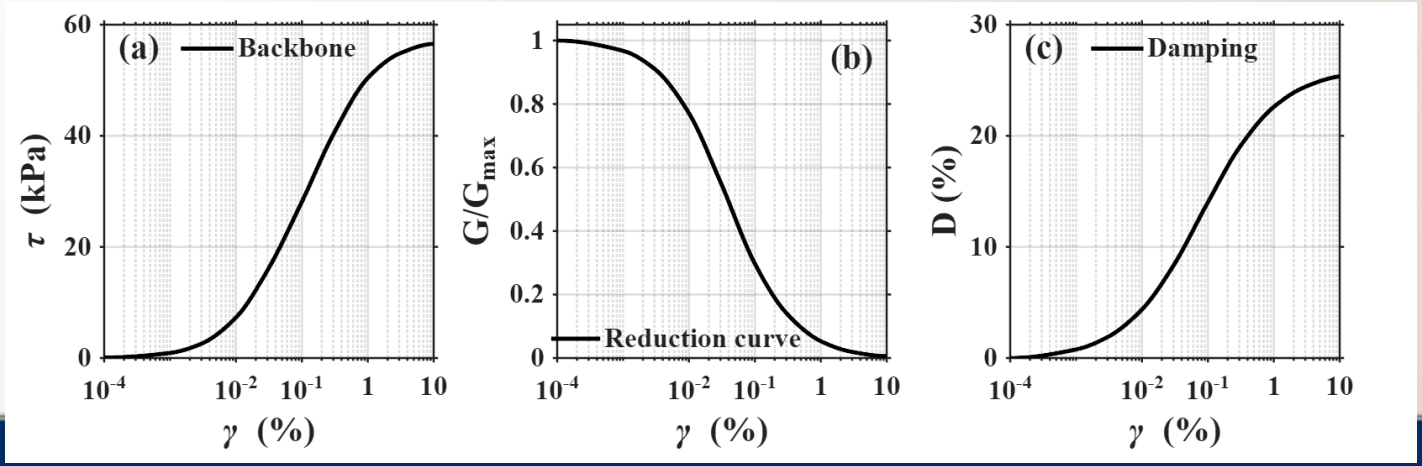
Landers motion (UnScaled) – PGA = 0.4g



LS-Dyna Modeling (2/2)

- Small-strain shear modulus
- Stress-strain behavior
- Small-strain damping (D_{min})
- MAT_HYSTERETIC_SOIL constitutive model, also referred to as MAT_079
- Large suite of input motions based on CMS framework (Humboldt Bay Power Plant site in California)
- PEER NGA-West2 database
- Noise and wavelet excitations used for system characterization
- 20-30 min run time



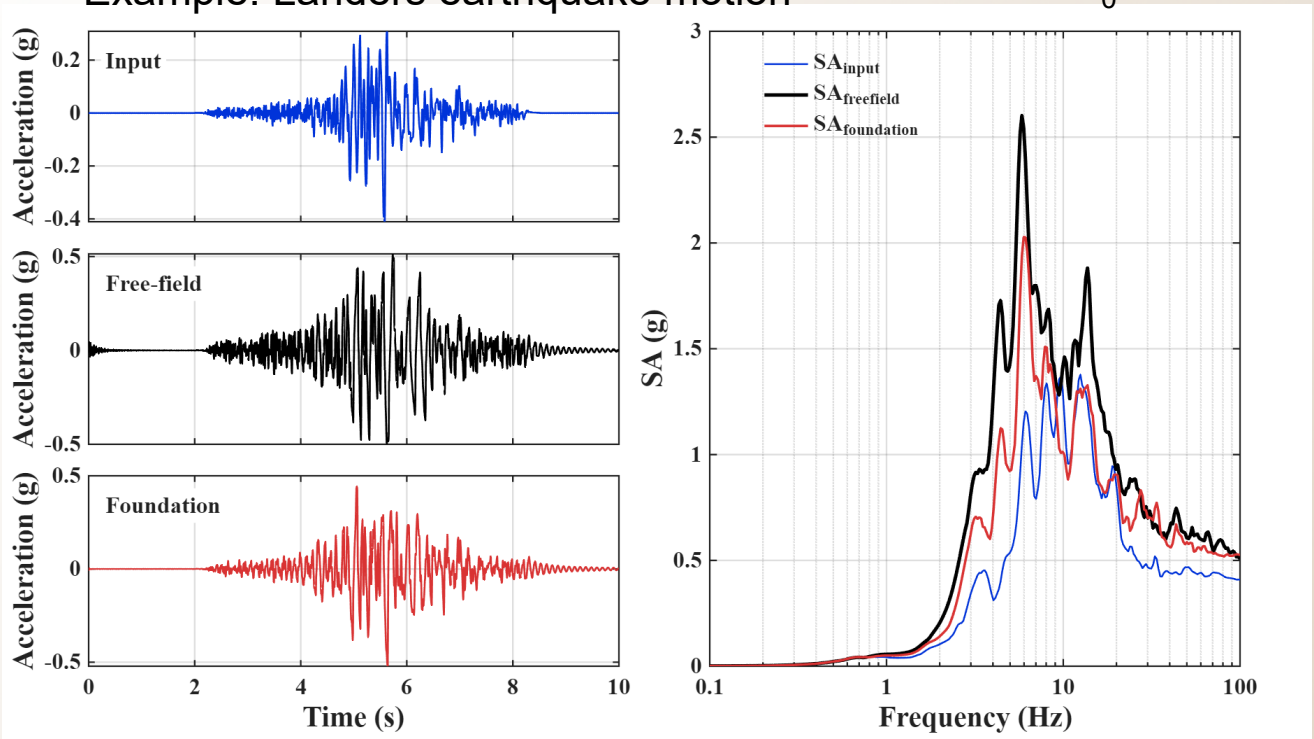


Type A Blind Prediction

- 60 seed motions were picked in 1st round of screening => 19 which produced meaningful kinematic effects were selected
- Scaled and unscaled ground motions were applied. Scaled motions yielded more conclusive results

Example: Landers earthquake motion

F_0= 10.1 Hz



Video (Landers motion, PGA = 0.4g)

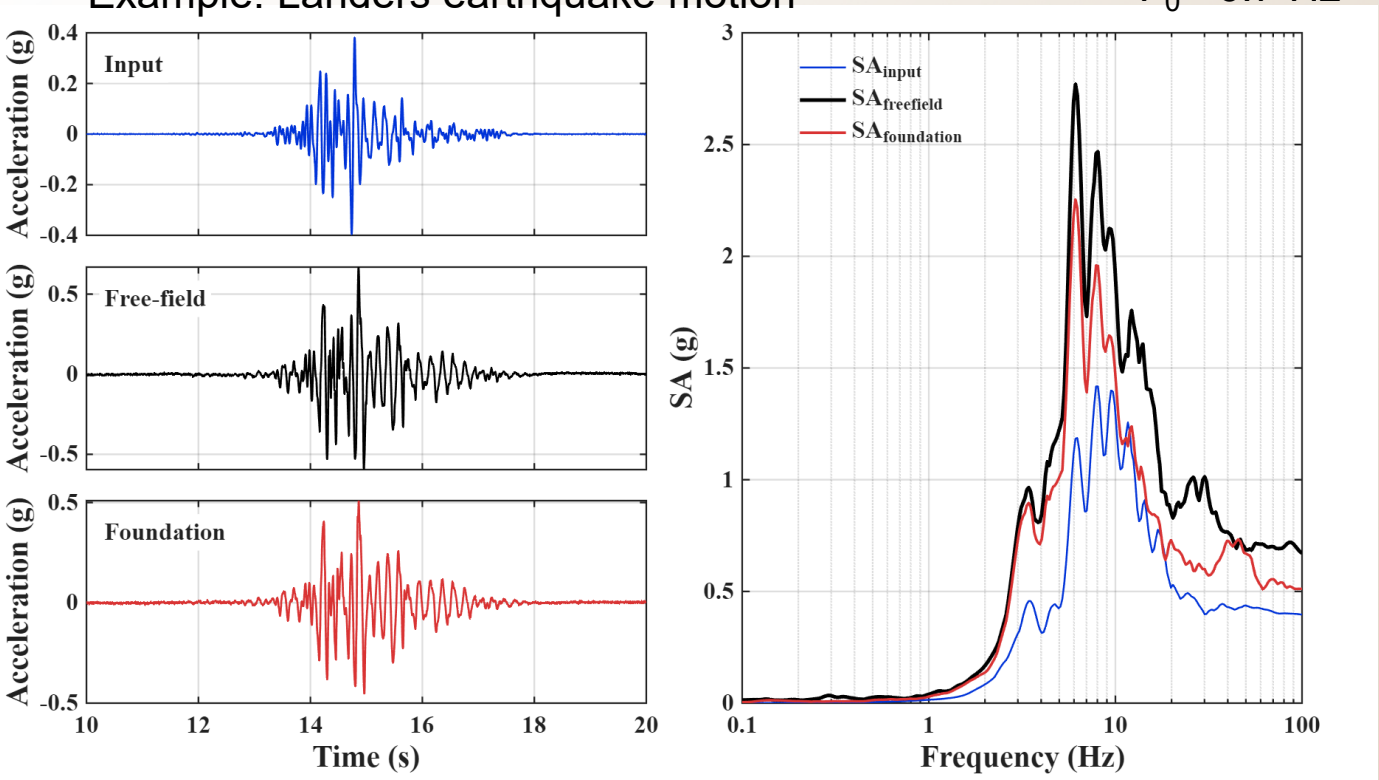


Experimental Results

- One specimen subjected to 73 shakings in total
- Free-field site response => amplification within broad frequency range
- Kinematic SSI effects => reductions in spectral accelerations at high frequencies

Example: Landers earthquake motion

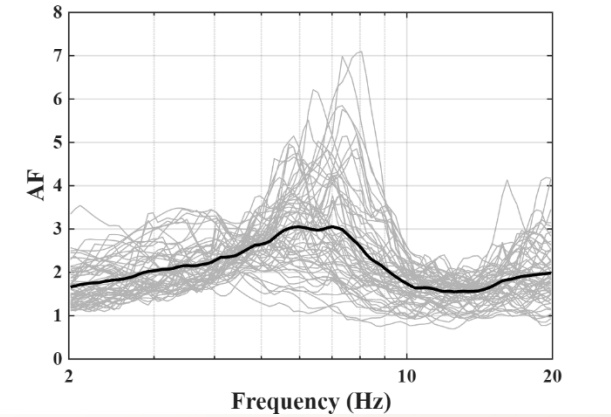
F_0= 6.7 Hz



Type C1 Prediction

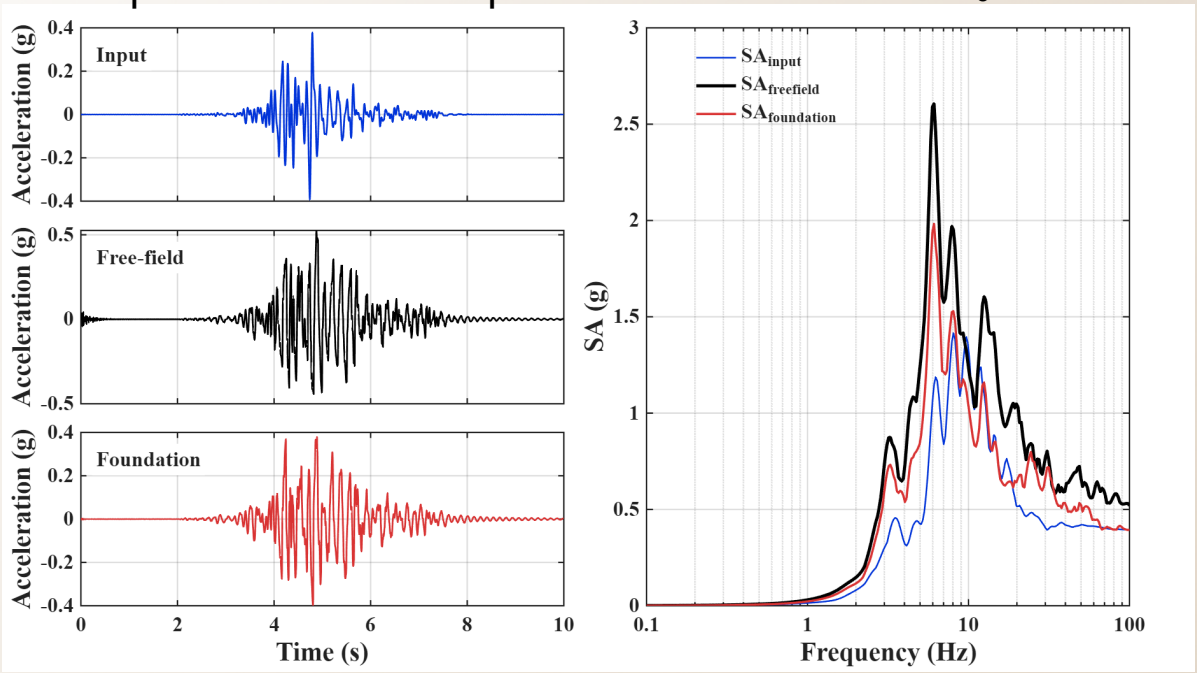
- Class C1 simulations used the achieved table acceleration histories recorded during the experiments, together with the as-built model ground properties
- No changes in the FE modeling assumptions, boundary conditions, etc

57 motions



Example: Landers earthquake motion

F_0= 6.7 Hz

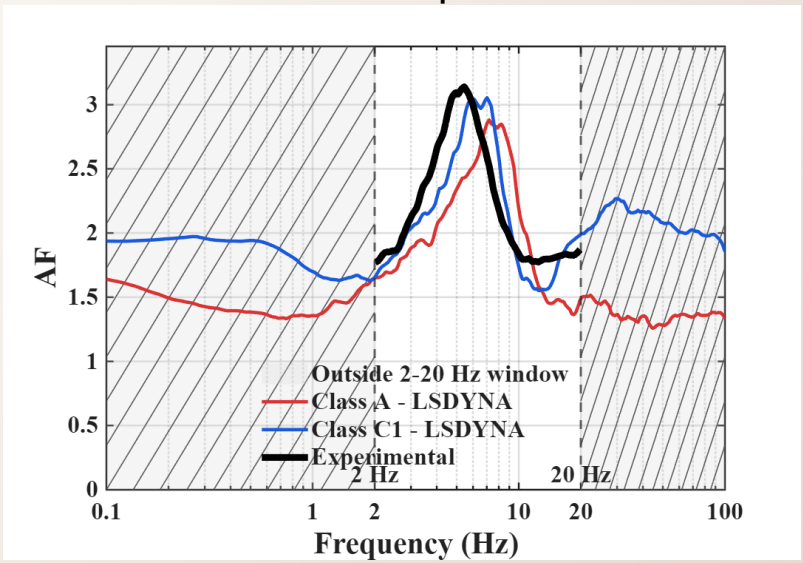


Overall Assessment of Predictions

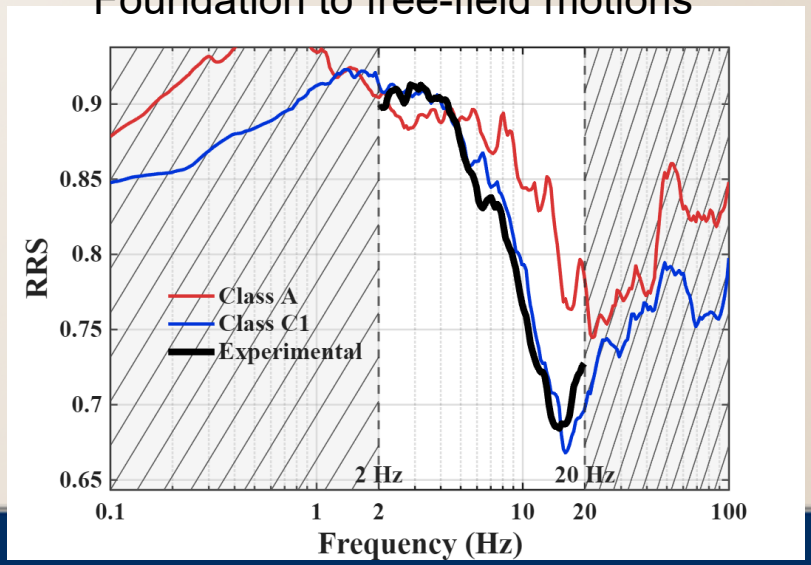
- Free-field response was improved in terms of amplitude and frequency content => small-strain dynamic characteristics played an important role
- Kinematic SSI effects presented in form of RRS were also enhanced
- No calibration was attempted as a part of Class C1 prediction

- Unique opportunity to obtain large-scale and realistic experimental data under bi-axial shakings that can be utilized for validation of 3D SSI models

Free-field to input motions



Foundation to free-field motions



Thank you & questions?

