PEER

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SOIL-STRUCTURE-INTERACTION SIMULATION MODELS

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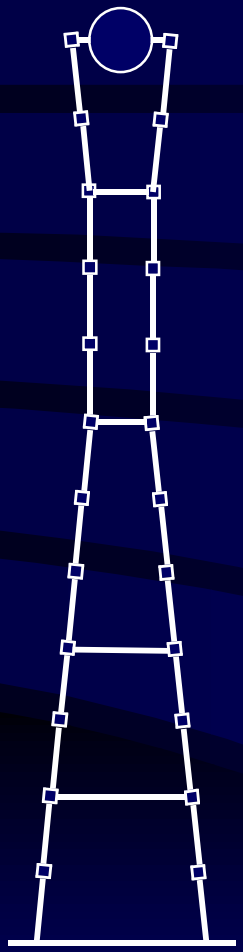
SEISMIC SSI- CONCLUSIONS

- Key components are: (foundation) soil, foundation system & structure.
- Key issue of Performance Based Design is the evaluation (estimation) of performance -> Requirement of robust, efficient & realistic numerical- analytical description of material response & system.
- Development & refinement of laboratory experiments which can accurately represent the problem are essential to validate "individual" constructs (numerical/conceptual blocks). It therefore provides an invaluable resource for calibrating numerical Codes-> Reduce inherent modeling uncertainty.
- Successful development of coupled site response and Soil-Pile-Superstructure Interaction analyses provides a Comprehensive framework for Performance Based Design for increasingly higher shaking levels

Structural Engineer's View of the World



Geotechnical Engineer's View of the World

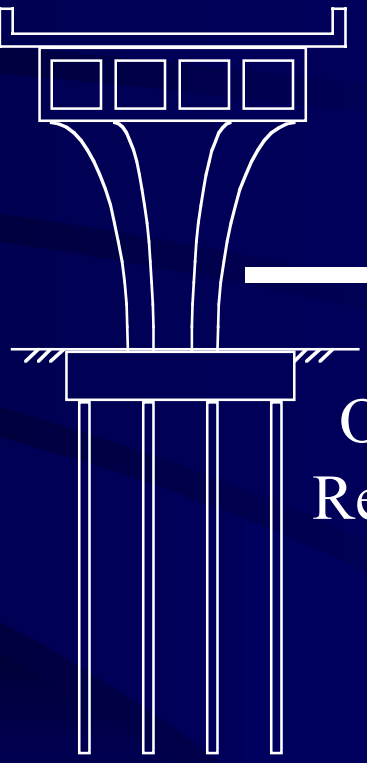
Courtesy of Dr. Lehman- University of Washington

SOIL-STRUCTURE INTERACTION

- Types of structures (buildings, bridges, bunkers)
- Transfer Function: Empirically or analytical description of the behavior of a structure given response at ground level.
- Estimation of performance
  - Shallow foundations- A lot of work still needed (i.e., mat foundation). A lot of interest - effect of structure embedment.
  - Deep Foundations- A lot of interest- Highway/ retrofit of Bridges and other structures in soft soils- SSI is extremely important.

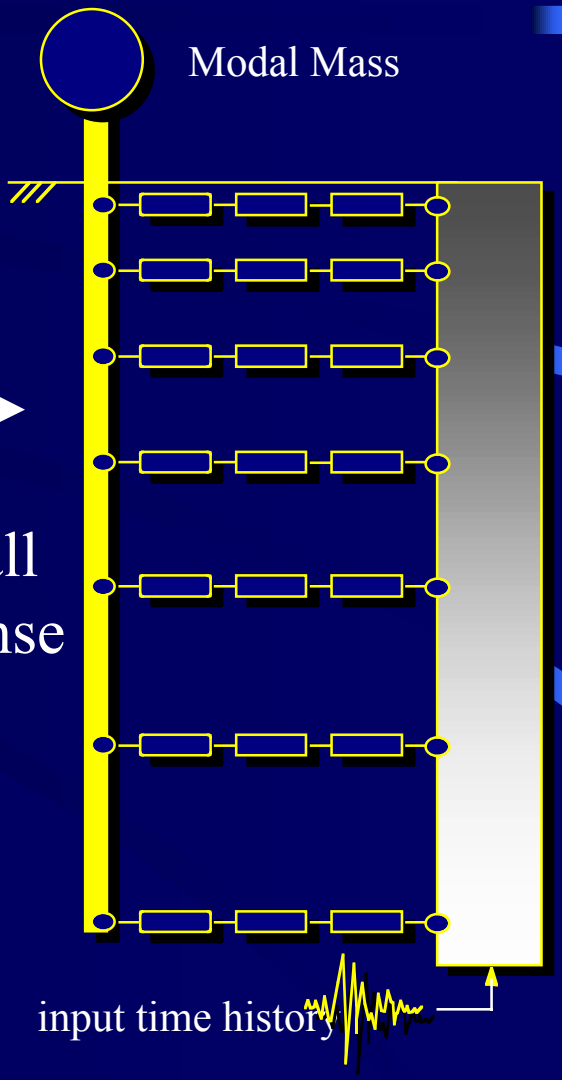
SSI- DEEP FOUNDATIONS
Soil-Pile-Superstructure Interaction

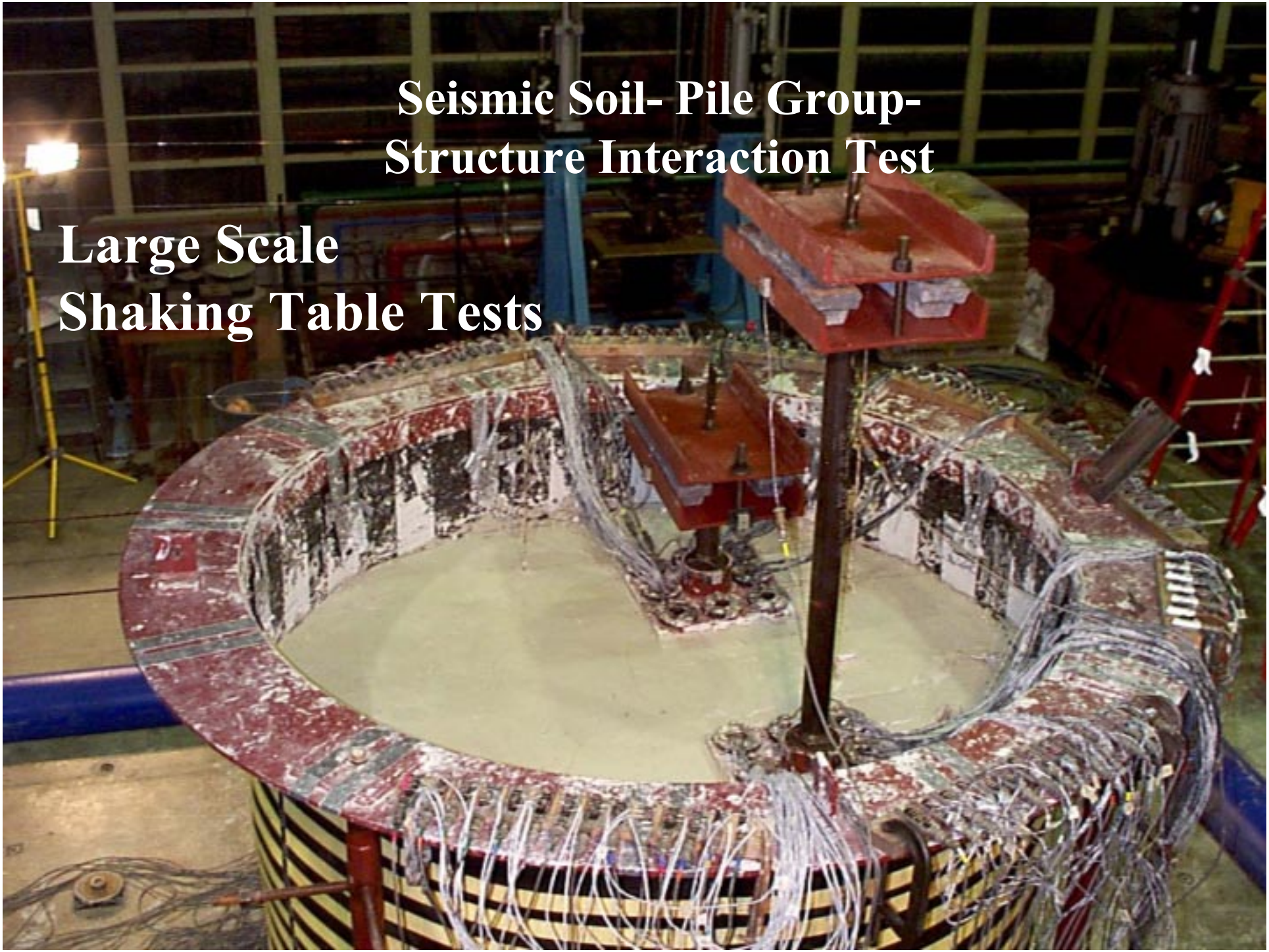
Coupled Model



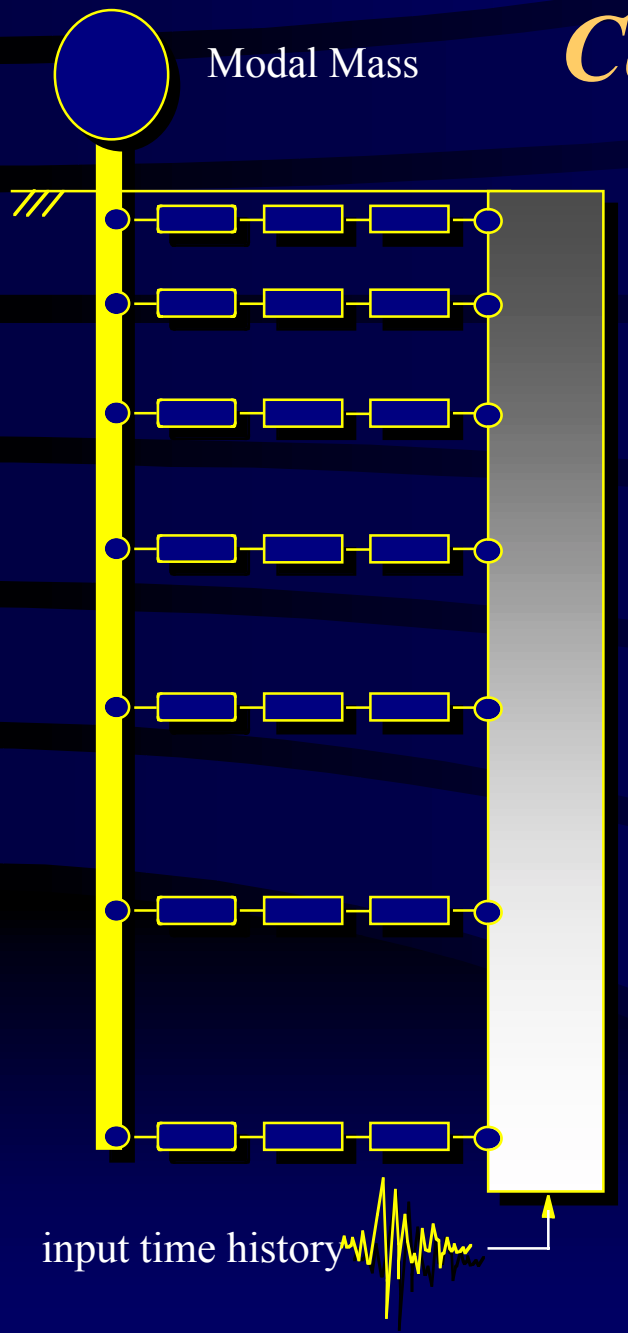
Overall Response

Earthquake Motion

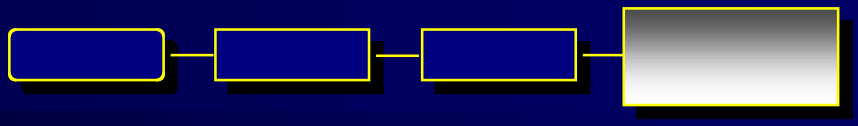



Seismic Soil- Pile Group-
Structure Interaction Test
Large Scale
Shaking Table Tests

Conceptual Soil - Pile Model

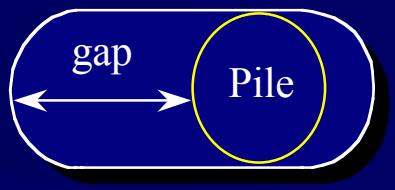


Soil Model

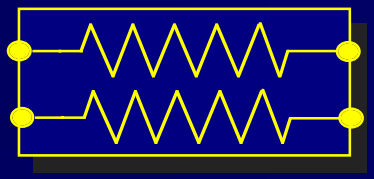


Interface **Near field** **Far field** **Free field**

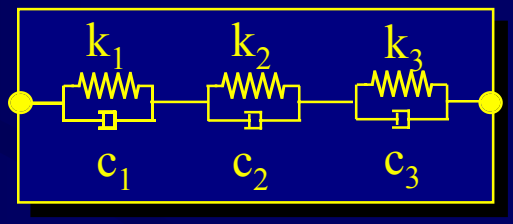
Interface element:
gapping = f(plastic soil deformation)



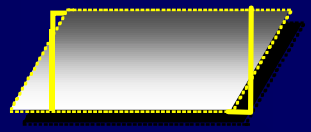
Near field element:
partitioned dynamic nonlinear p-y/t-z spring = f(strain rate, #cycles, strain reversals)



Far field element:
radiation damping = f(soil nonlinearity in near and free field)

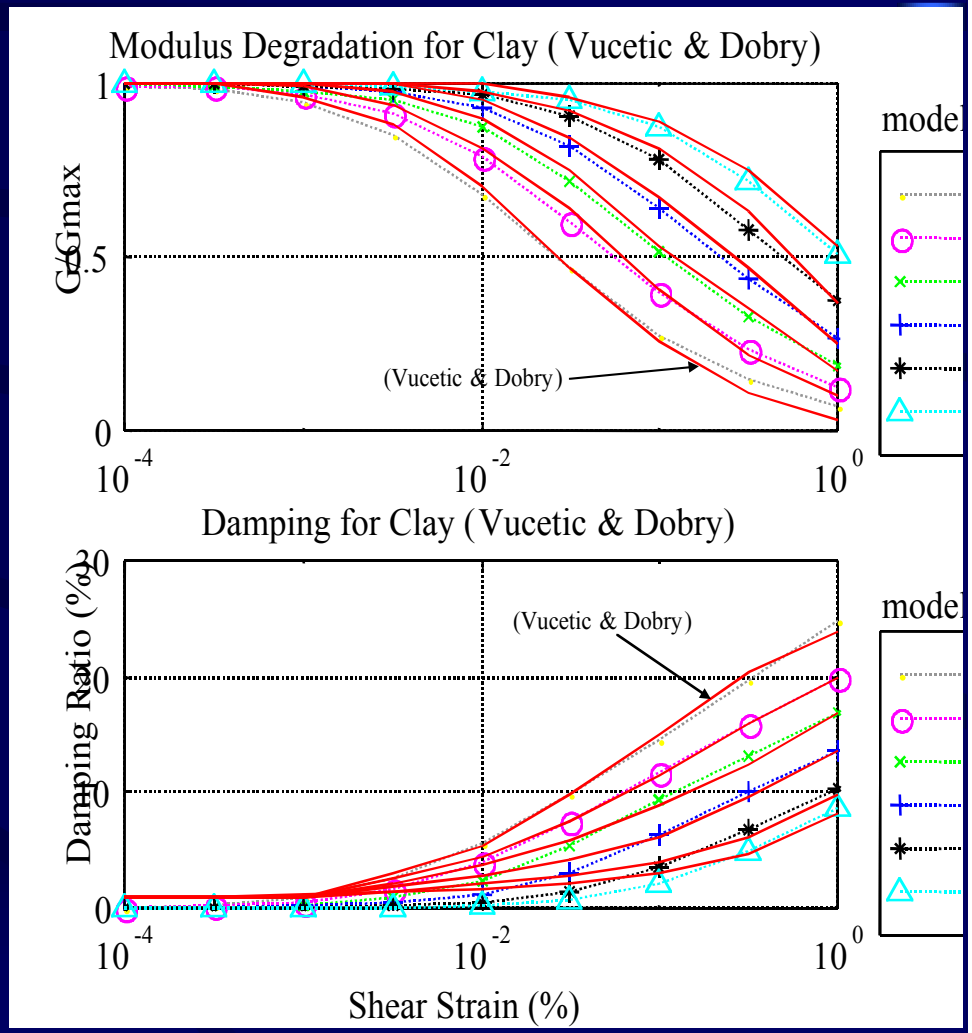


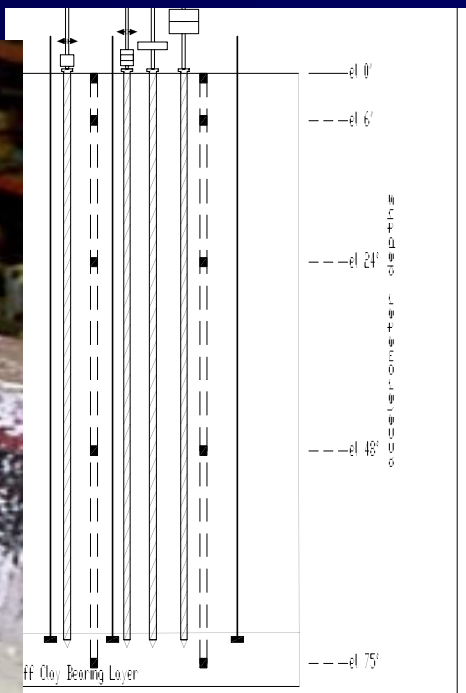
Free field element:
time domain site response inputs motions at nodes



NONLINEAR SITE RESPONSE ANALYSES- MODEL

- KEY ELEMENTS:
  - ABILITY TO MODEL SMALL STRAIN NON-LINEARITY AND DAMPING CHARACTERISTICS
  - FLEXIBILITY TO REALISTICALLY DESCRIBE RESPONSE FROM SMALL TO LARGE STRAINS
  - CORRESPONDENCE WITH MEASURED SOIL BEHAVIOR - ESTABLISHED PARAMETER DETERMINATION
  - CHARACTERIZATION OF UNCERTAINTY





Test 11

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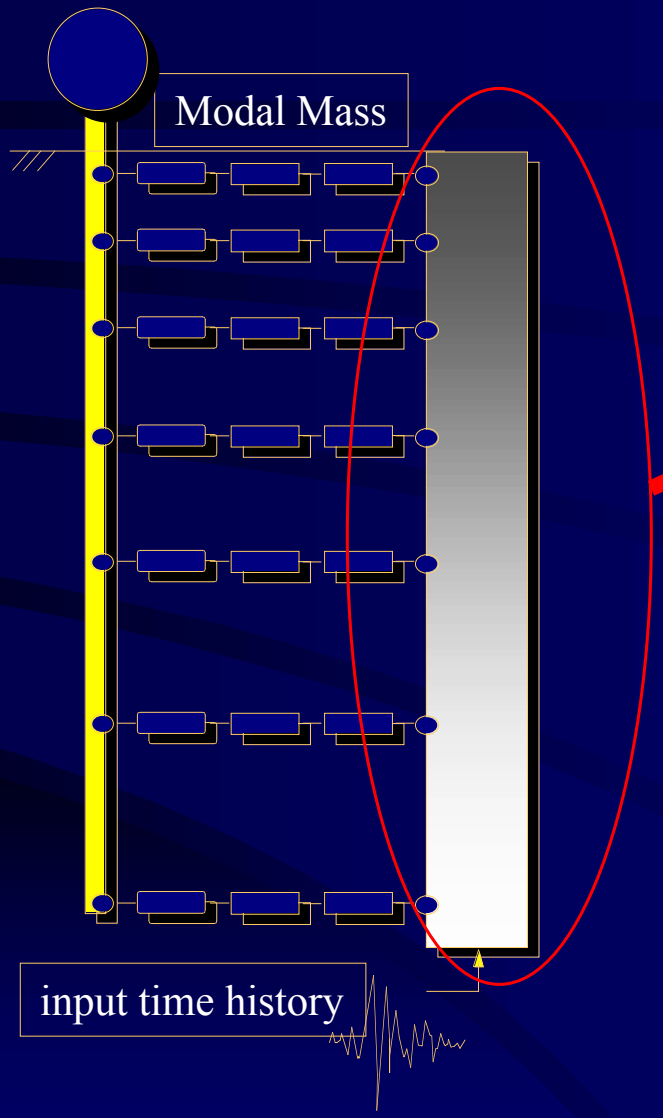
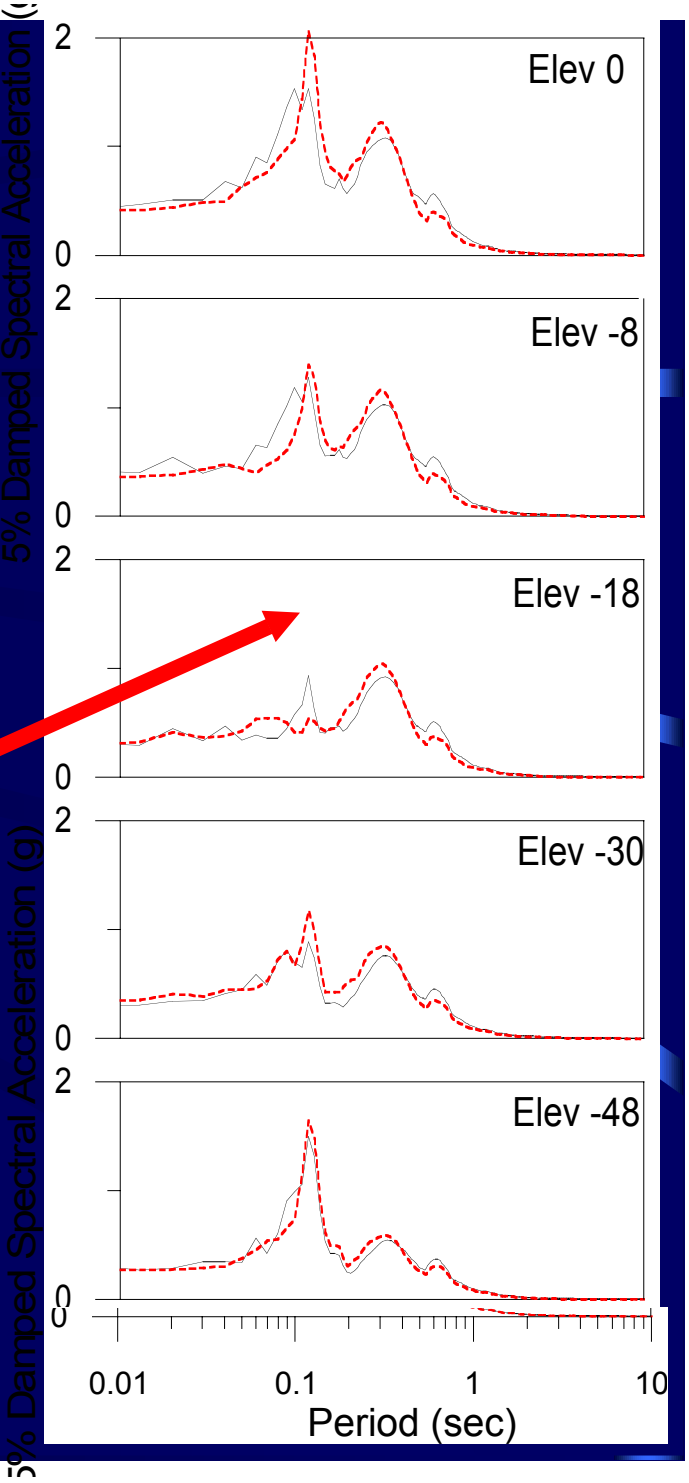
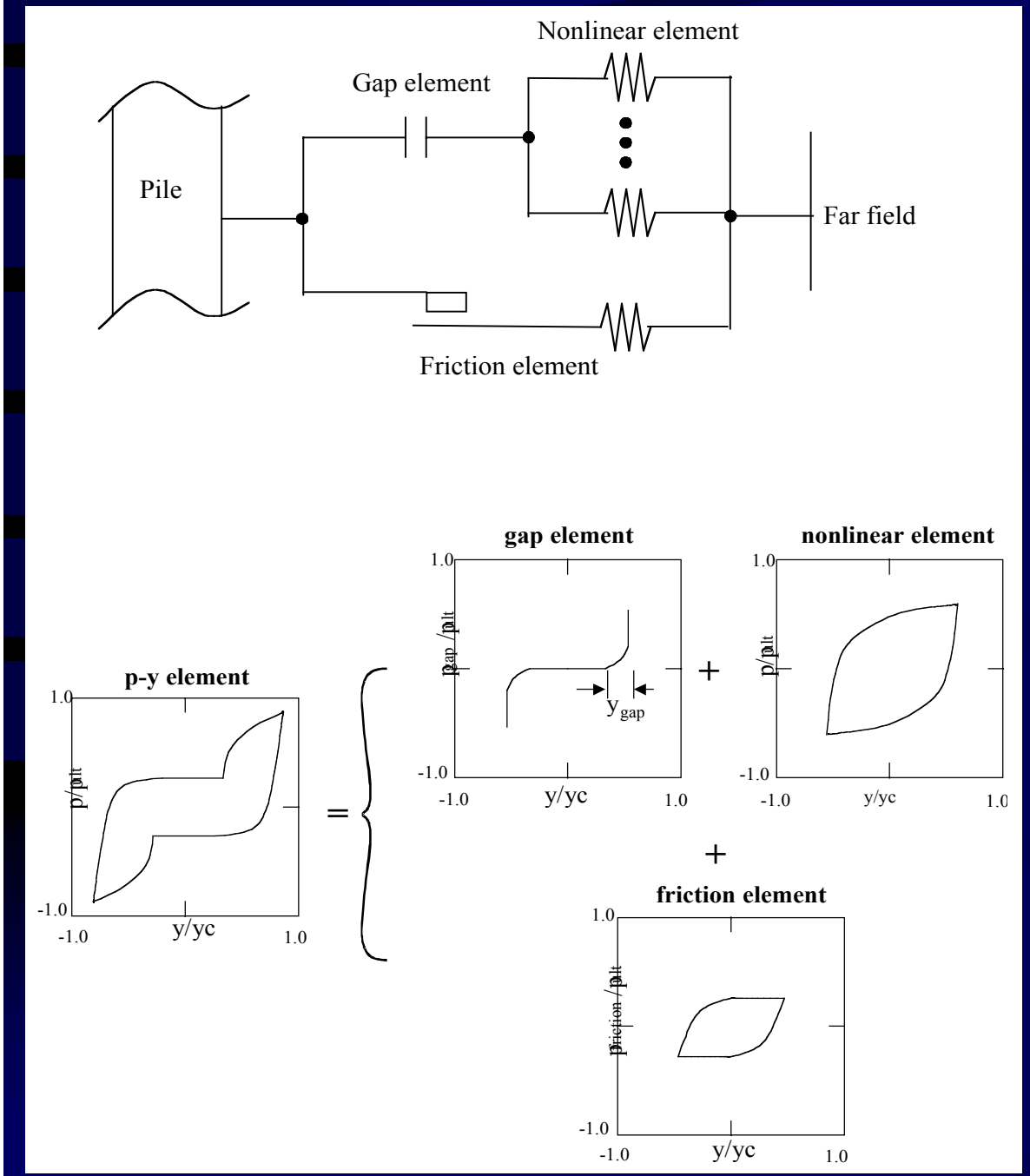
NONLINEAR SITE RESPONSE ANALYSIS CALIBRATED with VERTICAL ARRAY INFORMATION

SPECTRAL ACCELERATION

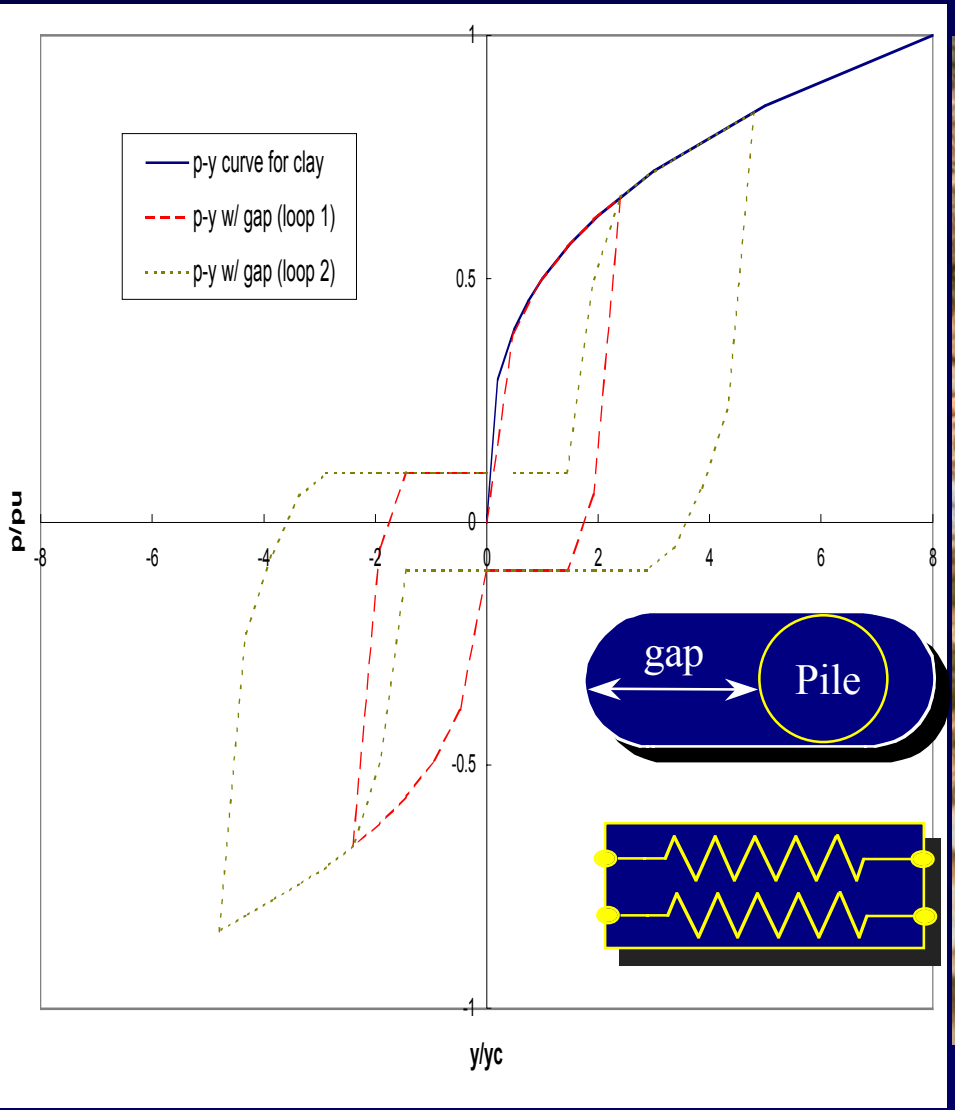


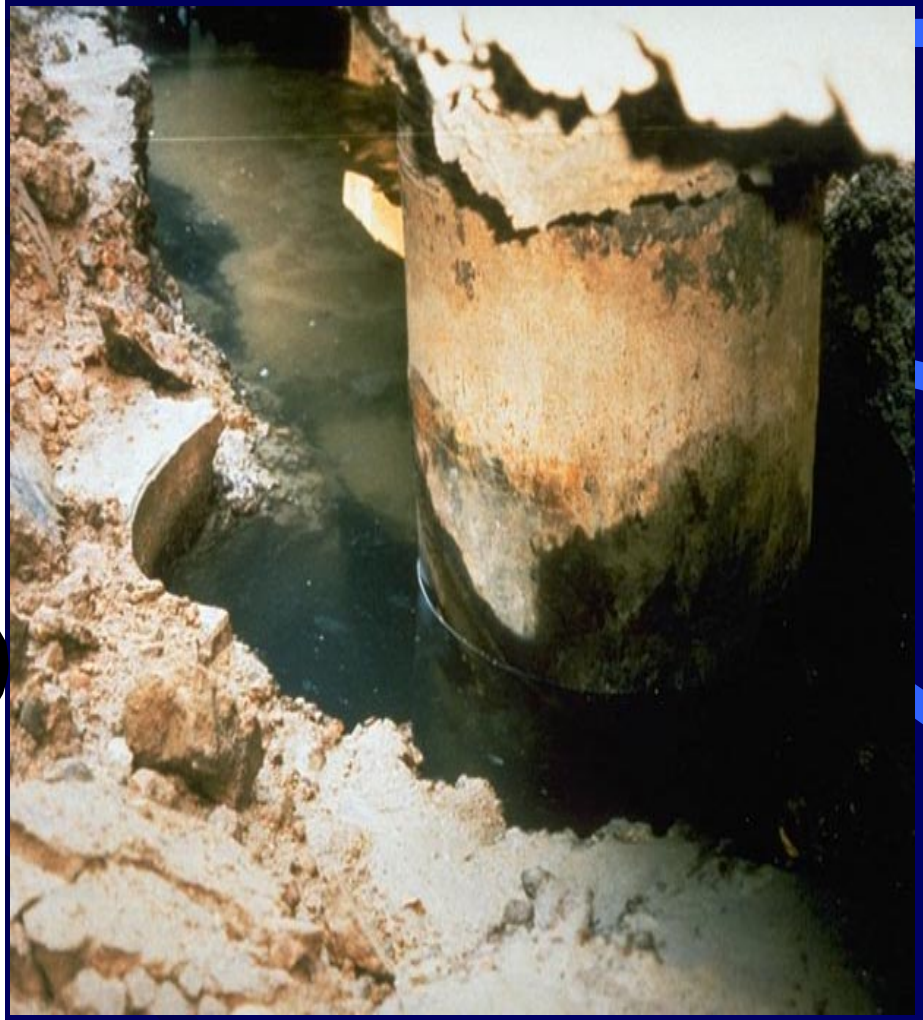




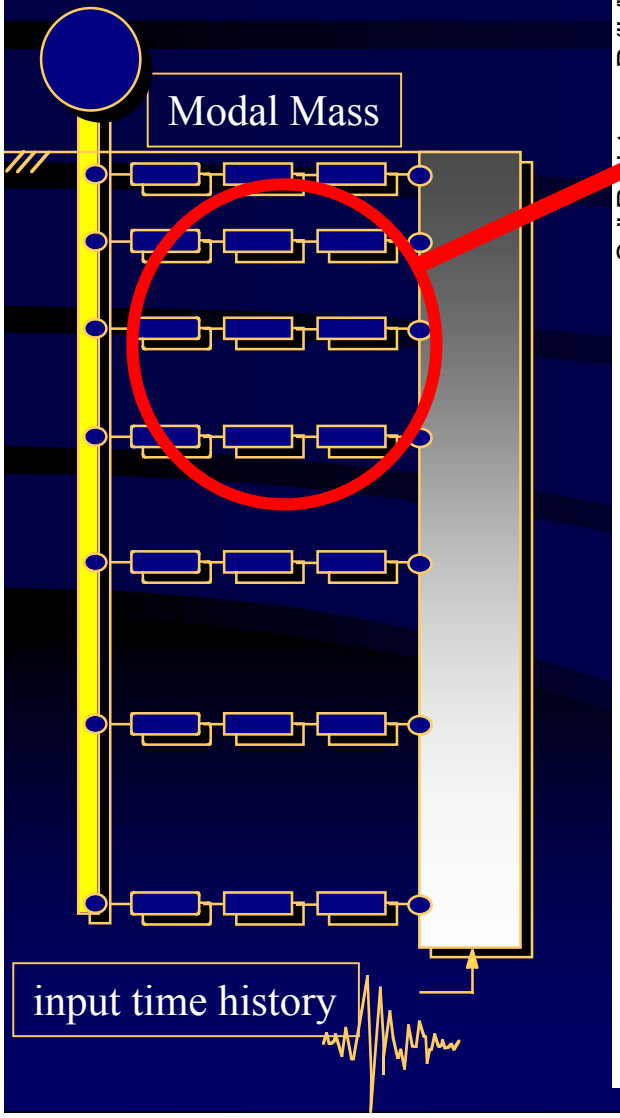
Formulation of nonlinear 1-D element

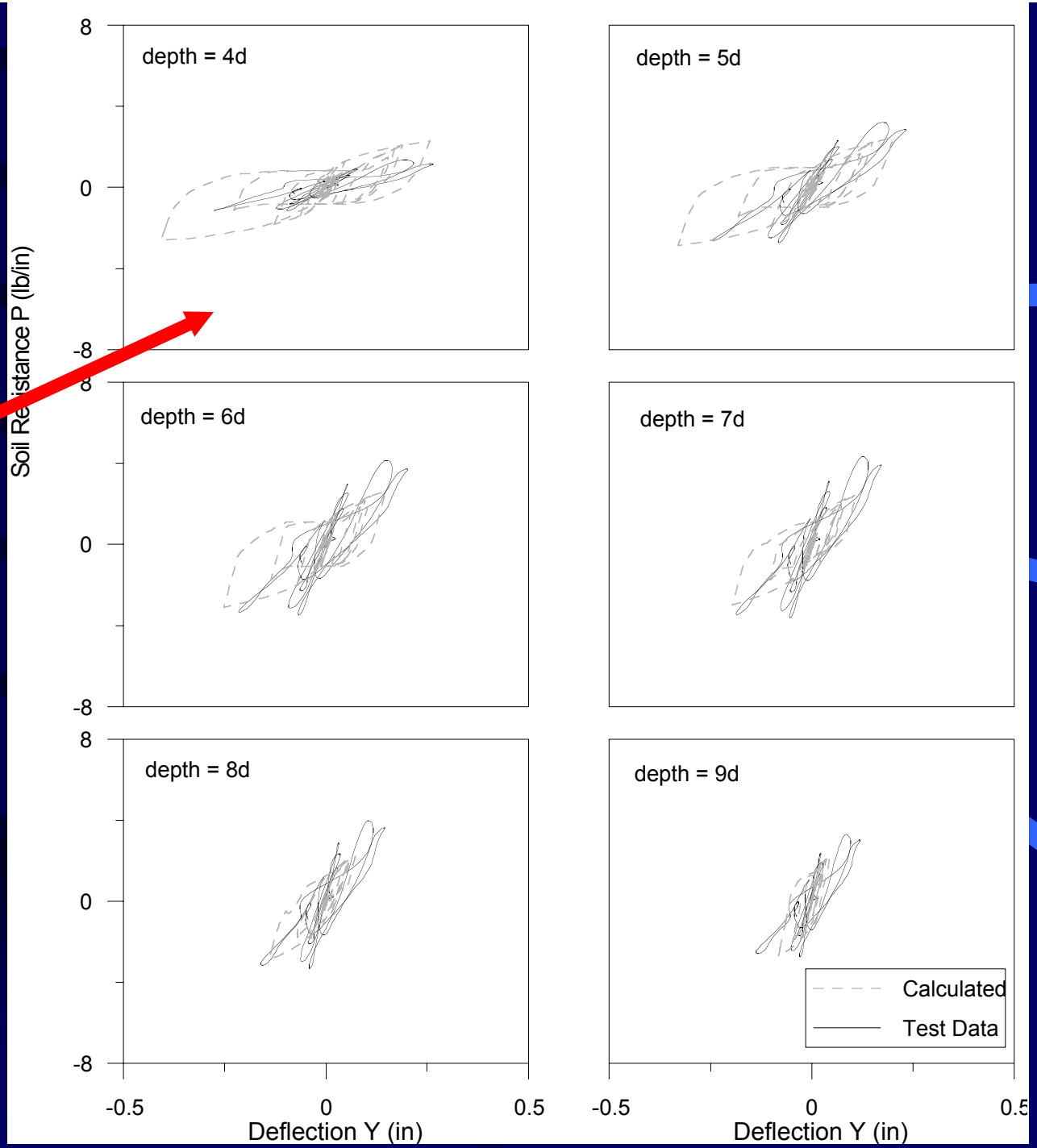
NUMERICAL CAPABILITIES -NONLINEAR p-y, t-z springs with Gapping Capabilities



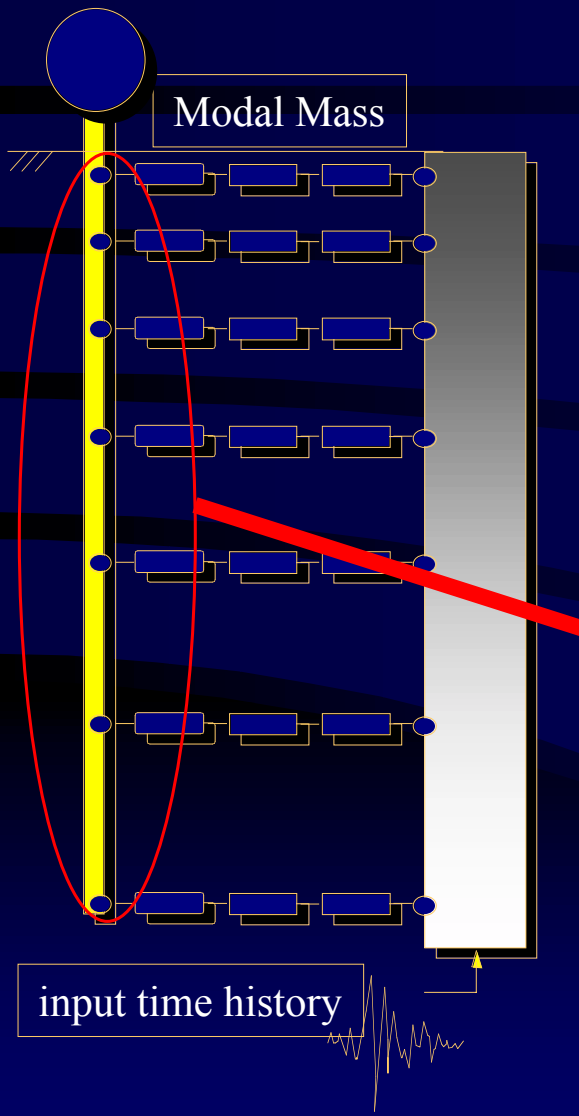


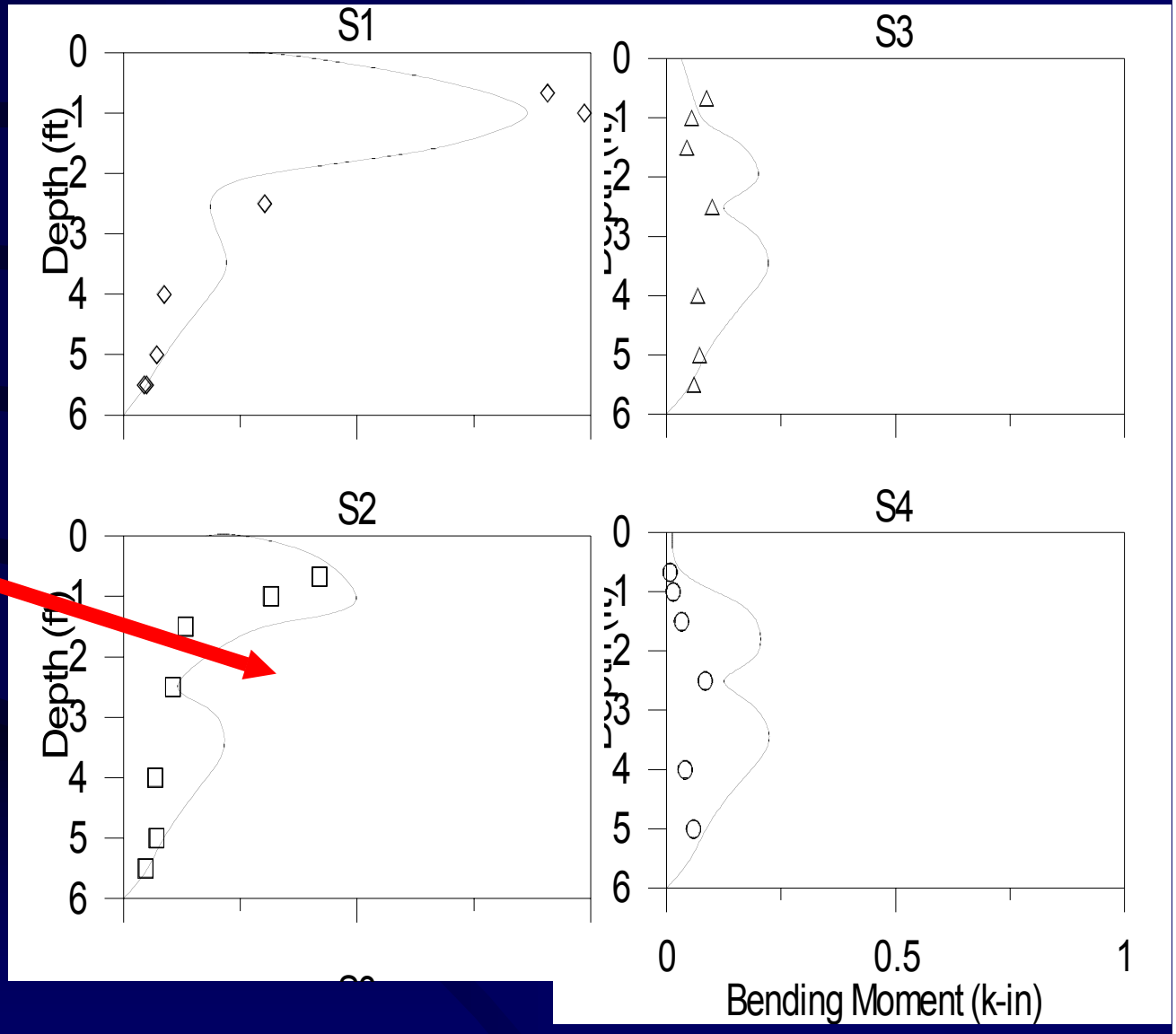
NEAR FIELD RESPONSE



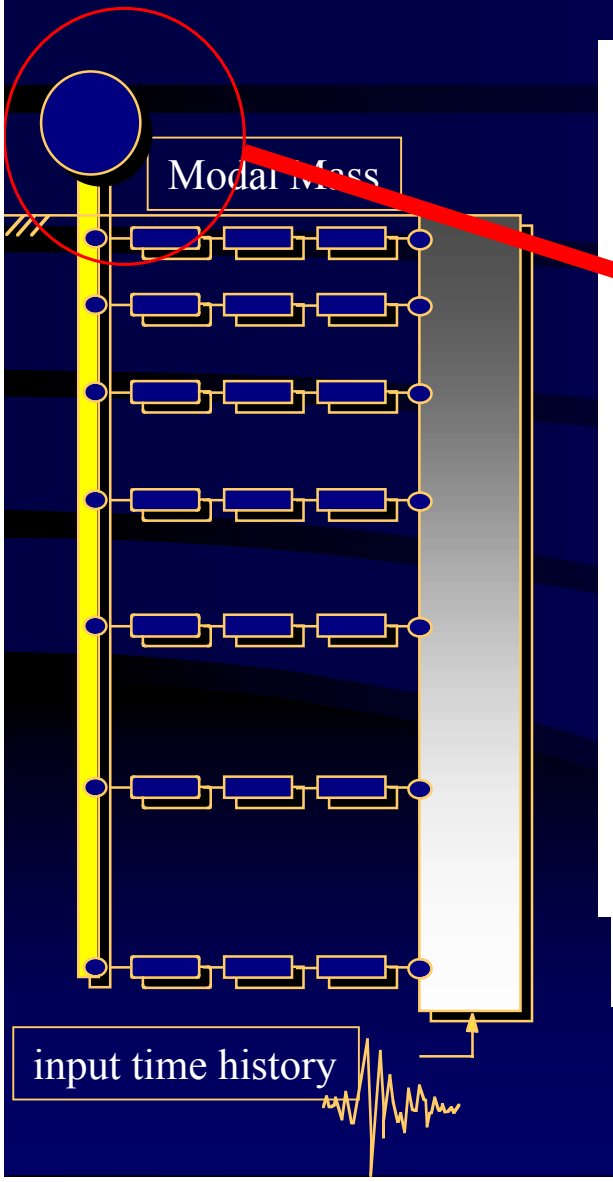


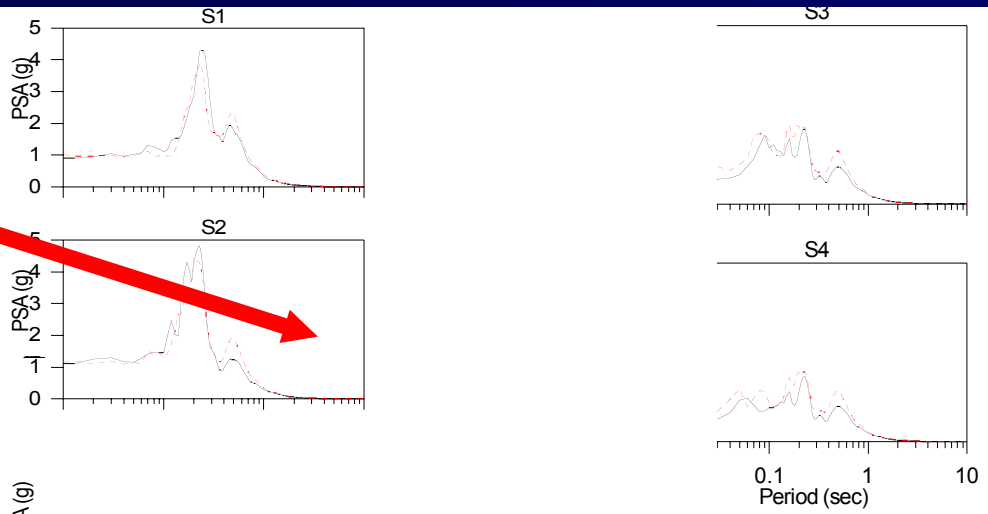
FOUNDATION RESPONSE- BENDING MOMENTS



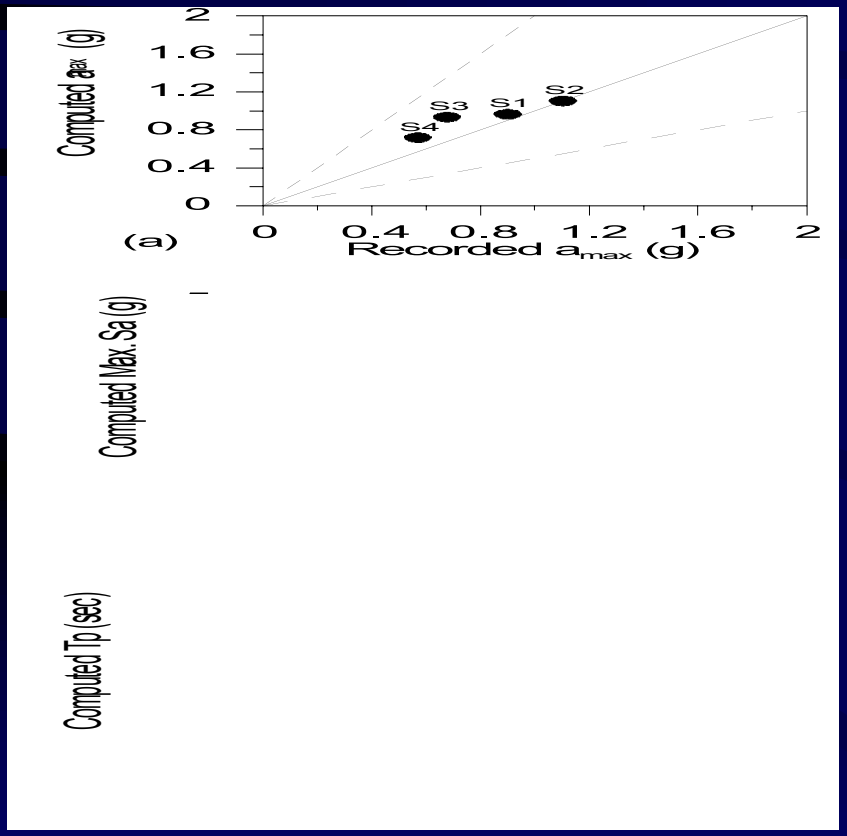


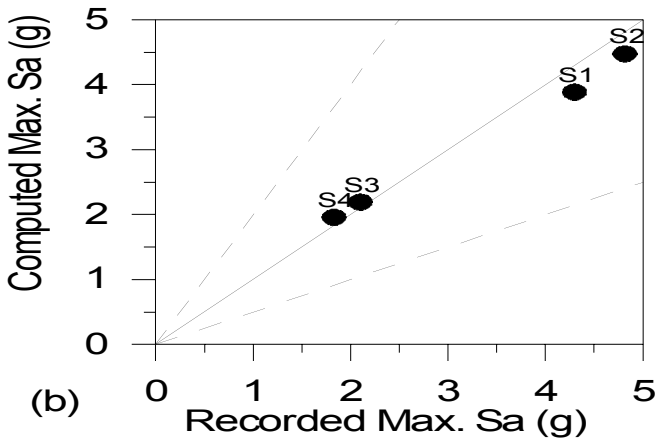
PREDICTION OF STRUCTURAL RESPONSE

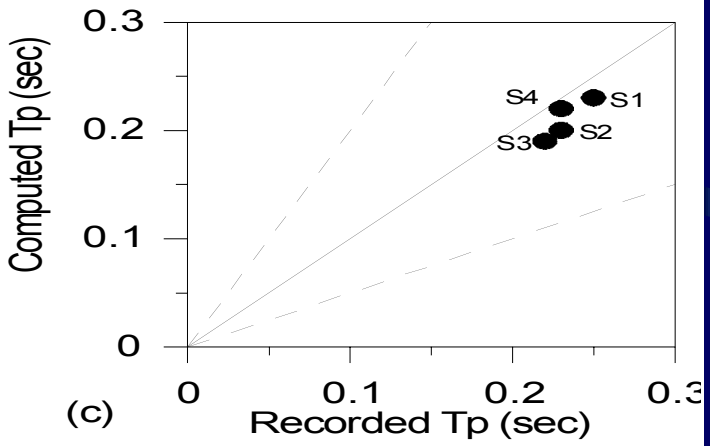




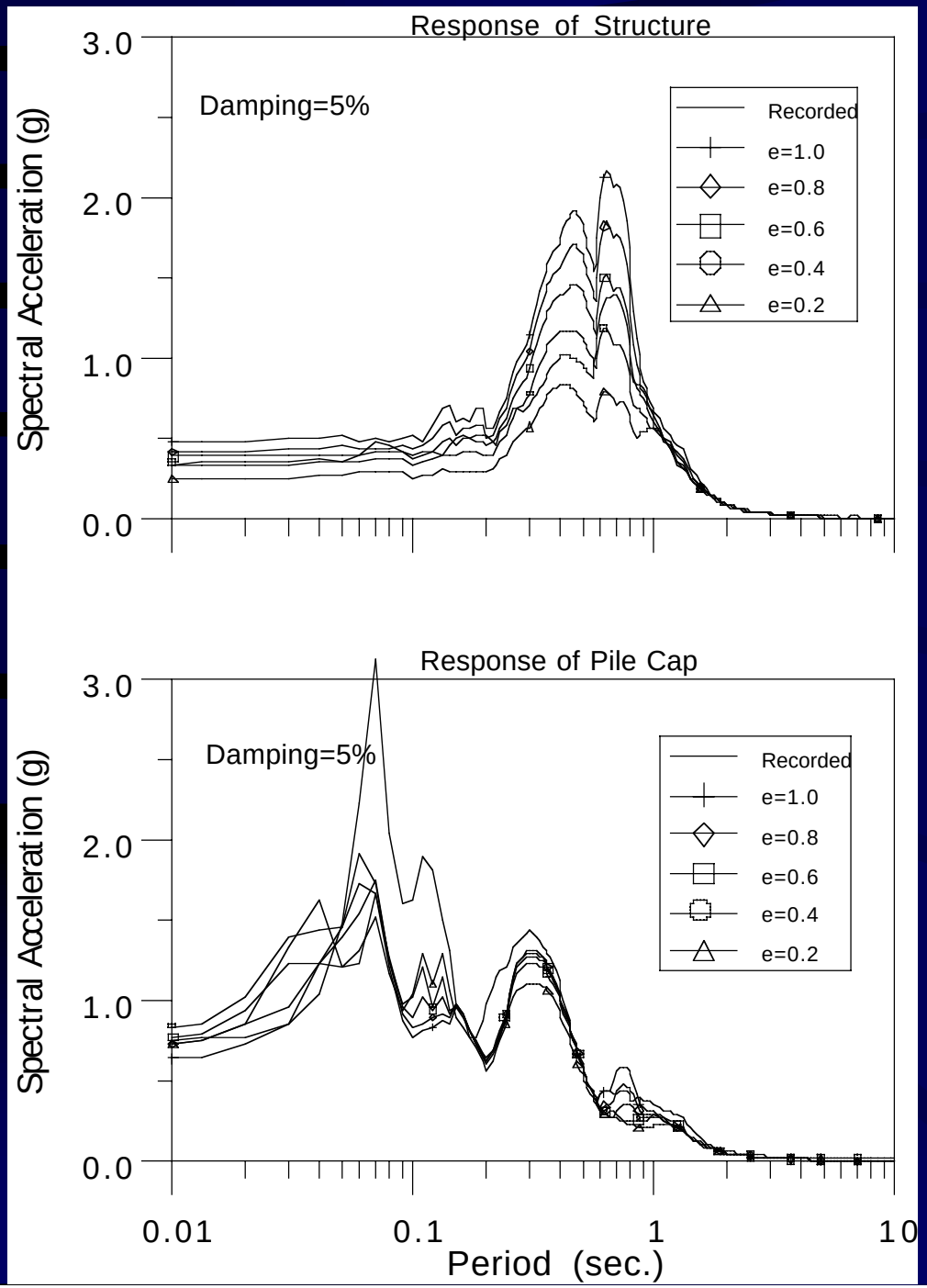
STRUCTURAL RESPONSE

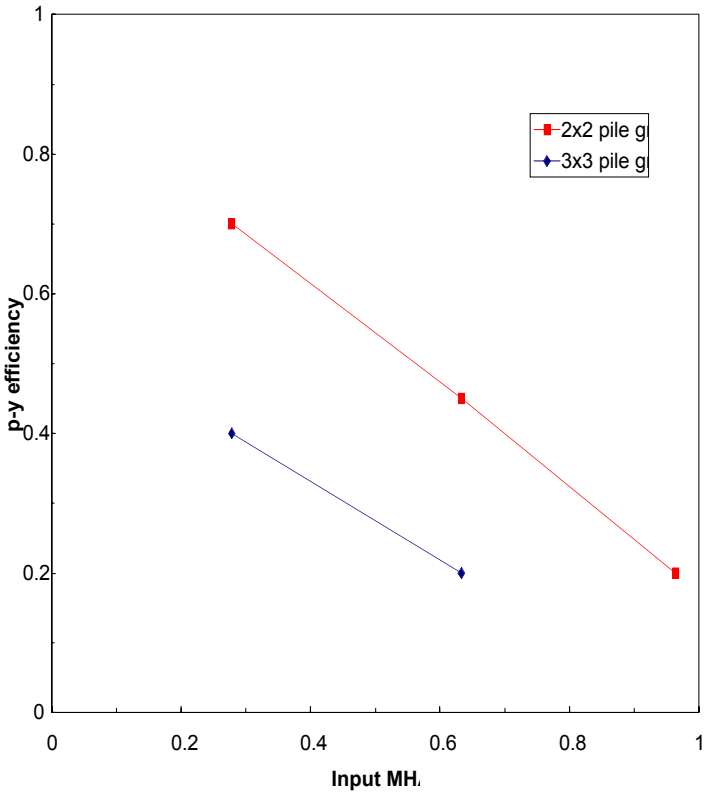




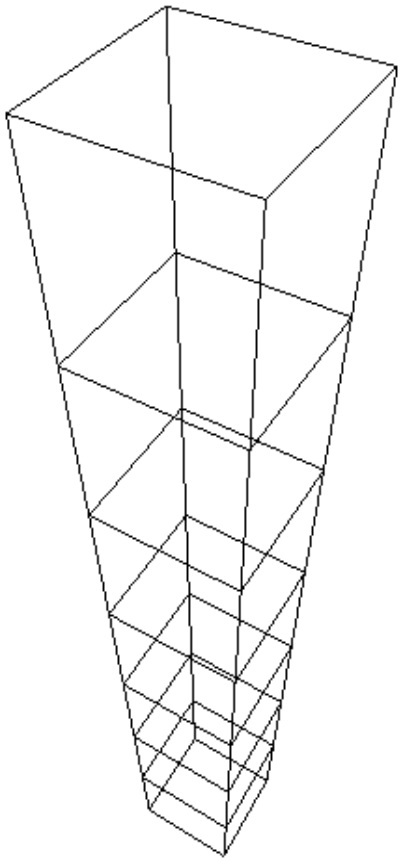


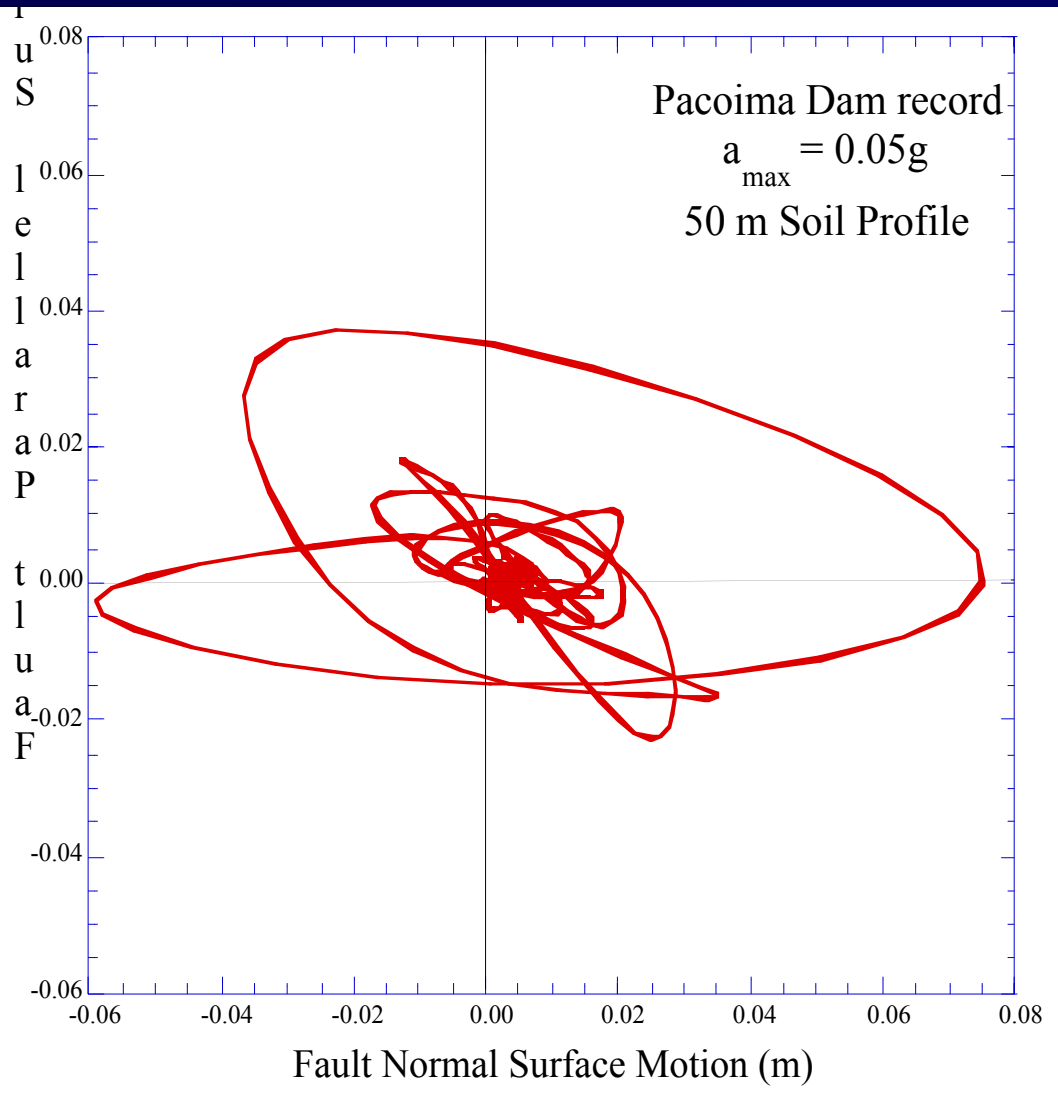
Performance of Pile Groups Equivalent Pier Approach

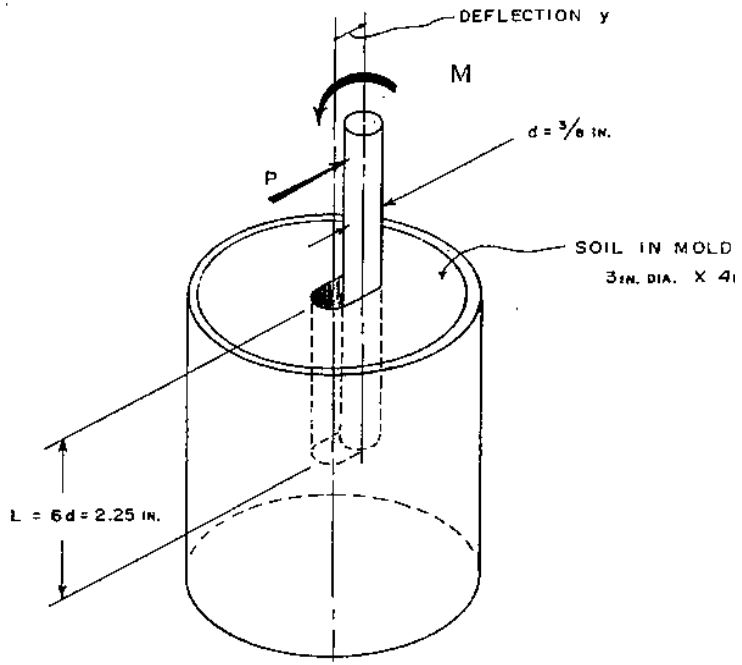


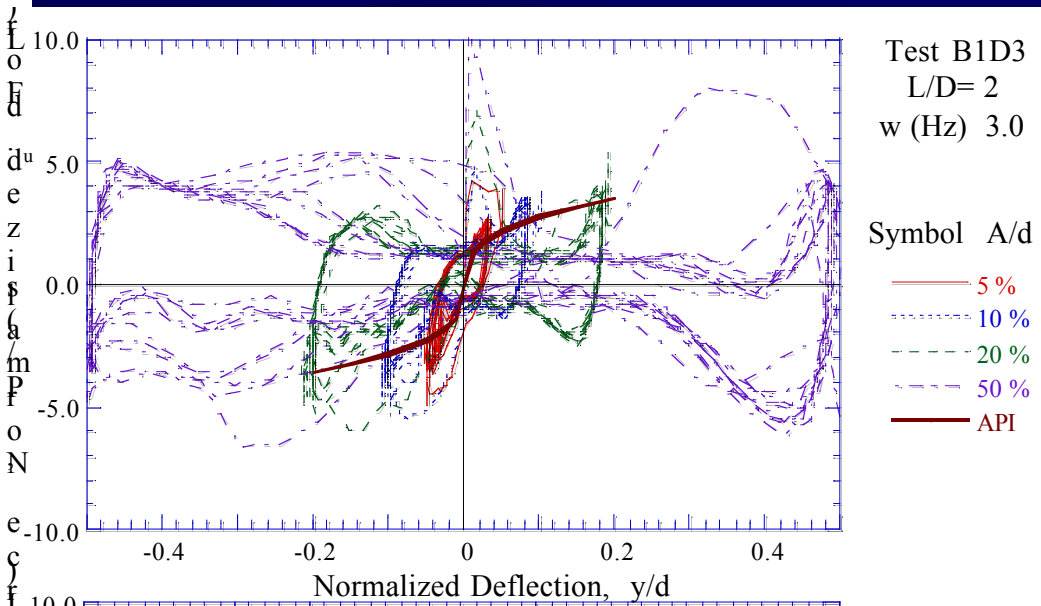


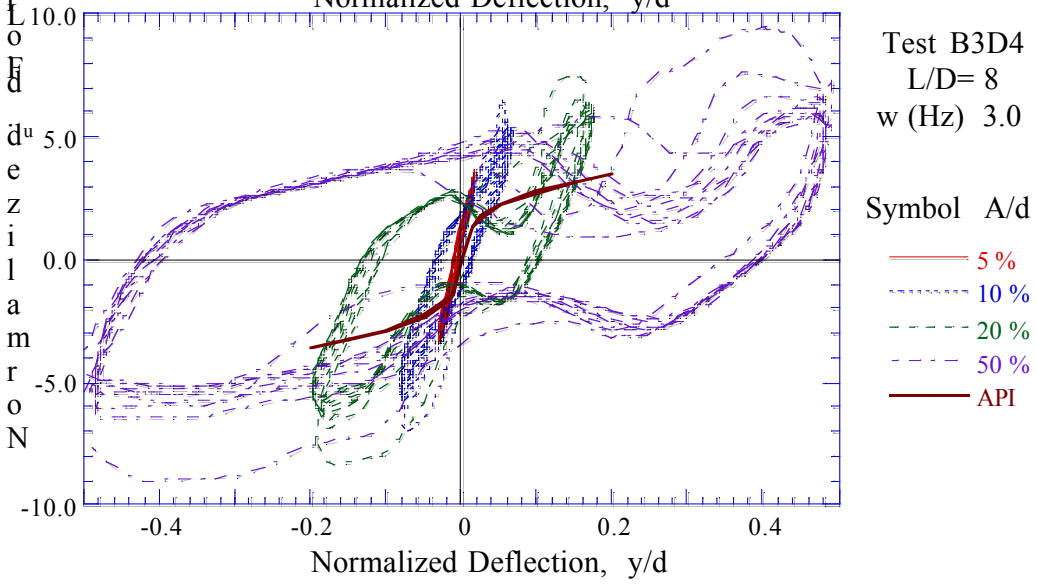
Multidirectional Shaking
2-D & 3-D Site Response Analyses






DEFLECTION y
M
d = 3/8 IN.
P
SOIL IN MOLD
3IN. DIA. X 4I
L = 6d = 2.25 IN.


Test B1D3
L/D= 2
w (Hz) 3.0
Symbol A/d
5 %
10 %
20 %
50 %
API
Normalized Deflection, y/d
10.0
5.0
0.0
-5.0
-10.0
-0.4
-0.2
0
0.2
0.4


Test B3D4
L/D= 8
w (Hz) 3.0
Symbol A/d
5 %
10 %
20 %
50 %
API
Normalized Deflection, y/d
10.0
5.0
0.0
-5.0
-10.0
-0.4
-0.2
0
0.2
0.4

MULTIDIRECTIONAL P-Y ELEMENTS

Numerical Tool

OpenSees Platform

* Nonlinear Site Response (2-D)
* Near Field, p-y

New Elements

Near Field, t-z and Q-z Capabilities

CONCLUSIONS- DEJA VU

- Key components are: (foundation) soil, foundation system & structure.
- Key issue of Performance Based Design is the evaluation (estimation) of performance -> Requirement of robust, efficient & realistic numerical- analytical description of material response & system.
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