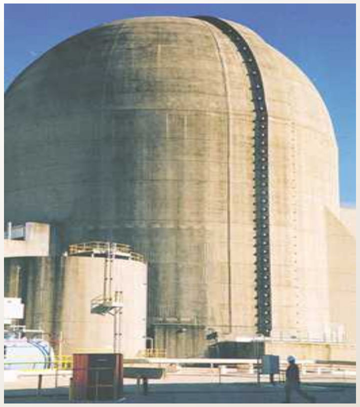
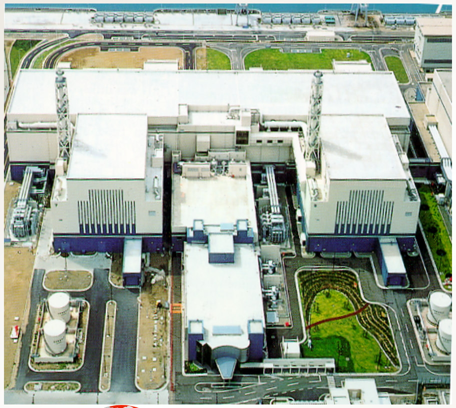
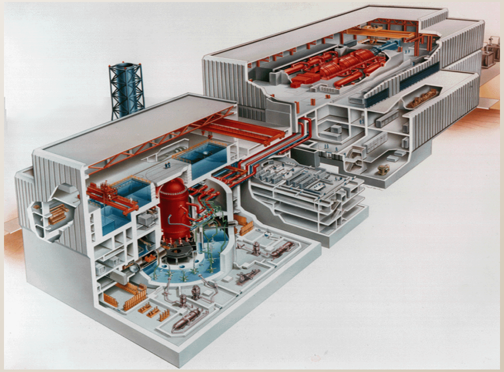
The State of the Computer Program SASSI



2015 SCEC SSI Workshop
University of Southern California
January 29, 2015

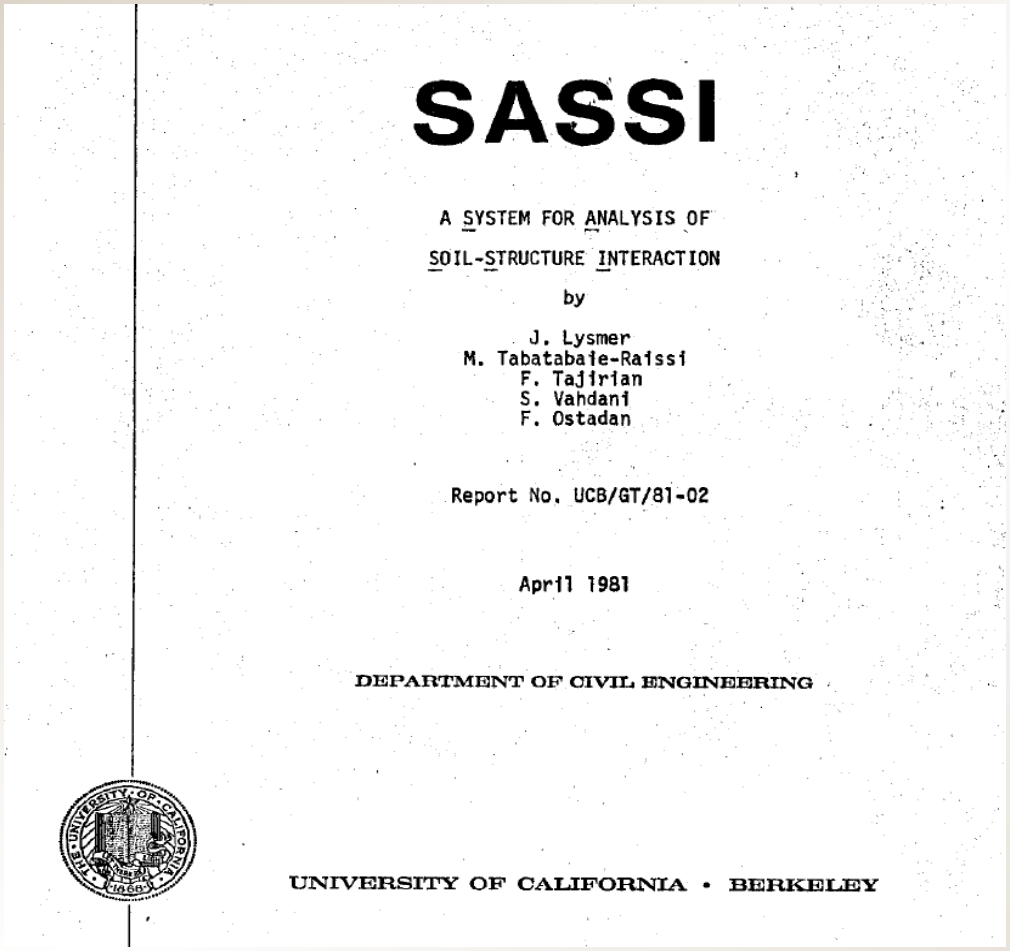
Farhang Ostadan
Bechtel Corporation





BECHTEL

Computer Program SASSI - Acknowledgement



SASSI

A SYSTEM FOR ANALYSIS OF

SOIL-STRUCTURE INTERACTION

by

J. Lysmer
M. Tabatabaie-Raissi
F. Tajirian
S. Vahdani
F. Ostadan

Report No. UCB/GT/81-02

April 1981

DEPARTMENT OF CIVIL ENGINEERING

UNIVERSITY OF CALIFORNIA • BERKELEY

SASSI2000
Included C C Chin

SASSI2010
Included Nan Deng

SUBSTRUCTURING METHODS

FINITE ELEMENT SUBSTRUCTURING METHODS

- Rigid boundary methods
- Flexible boundary methods
- Flexible volume method
- Subtraction method

SUBSTRUCTURING METHODS

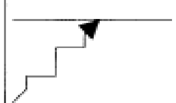
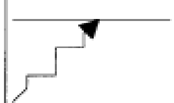
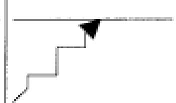
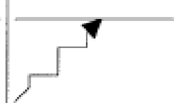
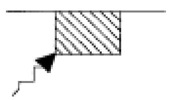
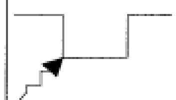
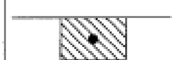
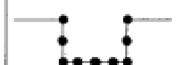
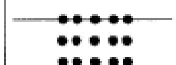
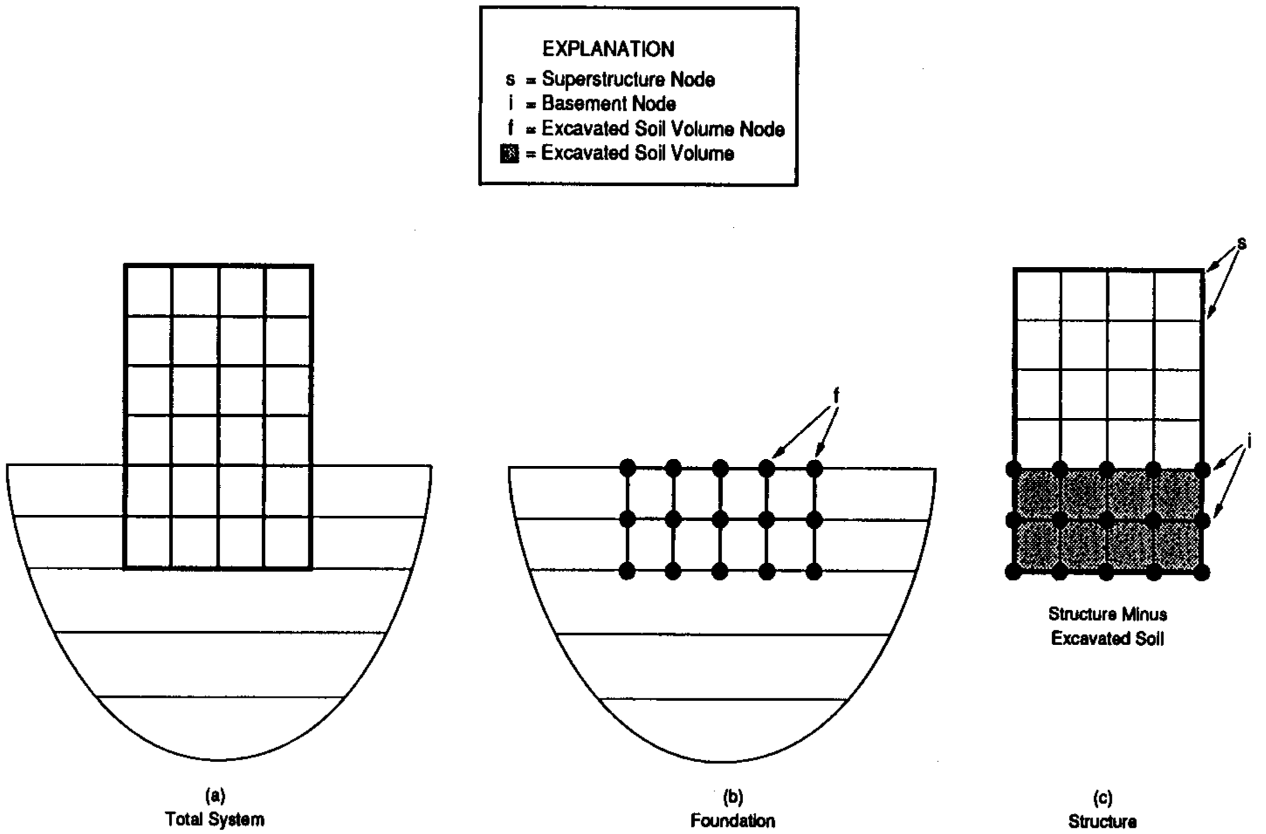
Analysis \ Method	Rigid Boundary	Flexible Boundary	Flexible Volume	Subtraction
Site Response Analysis (a)				
Scattering Analysis (b)			None	None
Impedance Analysis (c)				
Structural Response Analysis (d)	Standard	Standard +	Standard +	Standard +

Figure 2.1-1. Summary of Substructuring Methods

SASSI



Substructuring in the Flexible Volume Method

SASSI

EQUATION OF MOTION

- Seismic Case

$$\begin{bmatrix} C_{ss} & C_{si} \\ C_{is} & C_{ii}-C_{ff}+X_{ff} \end{bmatrix} \begin{Bmatrix} U_s \\ U_f \end{Bmatrix} = \begin{Bmatrix} 0 \\ X_{ff} \cdot U_f' \end{Bmatrix}$$

- Force Vibration Case

$$\begin{bmatrix} C_{ss} & C_{si} \\ C_{is} & C_{ii}-C_{ff}+X_{ff} \end{bmatrix} \begin{Bmatrix} U_s \\ U_f \end{Bmatrix} = \begin{Bmatrix} P_s \\ P_f \end{Bmatrix}$$

$$C = K - \omega^2 M$$

SASSI – Recent Developments

- Extensive verification of SASSI program – Ongoing work by the DOE Committee
  - ✓ Draft 2000-page report has been issued
  - ✓ Final report due in 2015
  - ✓ Guidance on the limitation of the parameters and use of SASSI features
  - ✓ No major findings
- SASSI2010, an improved solver, mufti-core operation, can handle very large models
- Implemented incoherency formulation
- Implemented random vibration theory

SASSI: Capabilities/Limitations

- Complete SSI analysis (free-field to SSI responses)
- Two- and three-dimensional SSI problems
- Rigid or flexible embedded foundation of any shape
- Structure-to-structure interaction
- Foundation with pile groups and battered piles
- Seismic waves, vertical and inclined body waves and surface waves
- Incoherent ground motion
- RVT using response spectrum as input
- Direct impact loading or harmonic loading
- Nonlinear analysis limited to equivalent linear modeling
- No nonlinear interface modeling
- No structural nonlinear modeling
- Two steps analysis is used for nonlinear analysis

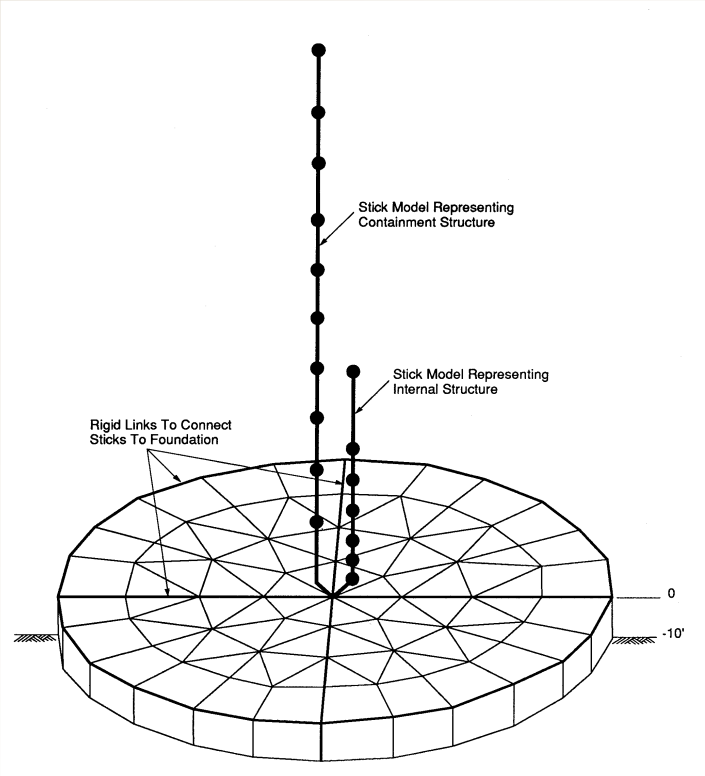
SASSI

SASSI continues to be used as the seismic SSI preferred code for nuclear and heavy industry

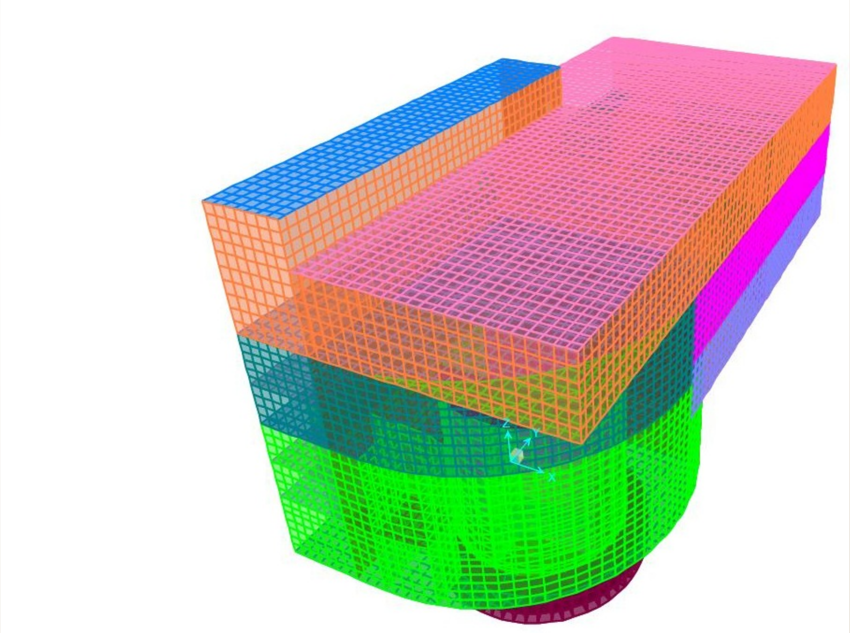
The state of the computer program SASSI is strong

Large 3D Models

1980s-CDC and Cray



Now, Desktop



Challenges

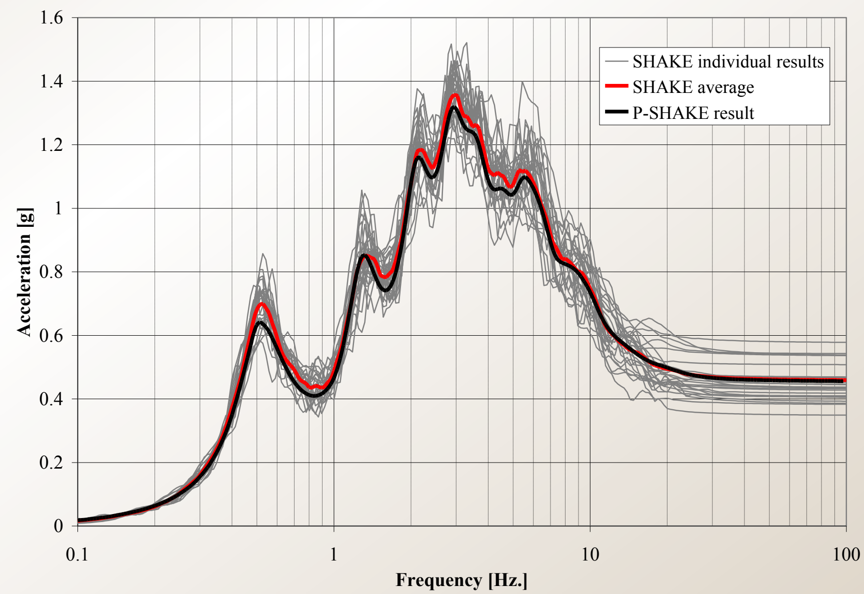
- We all know that bigger is not necessarily better
- We also witness the trend that no big model is big enough
- SSI analysis is a complex analysis and experienced in-depth review of the results is lacking in practice

…the basics apply to the most sophisticated structures

Ben Gerwick, Jr., 1988
(1919-2006)

Time History Issue

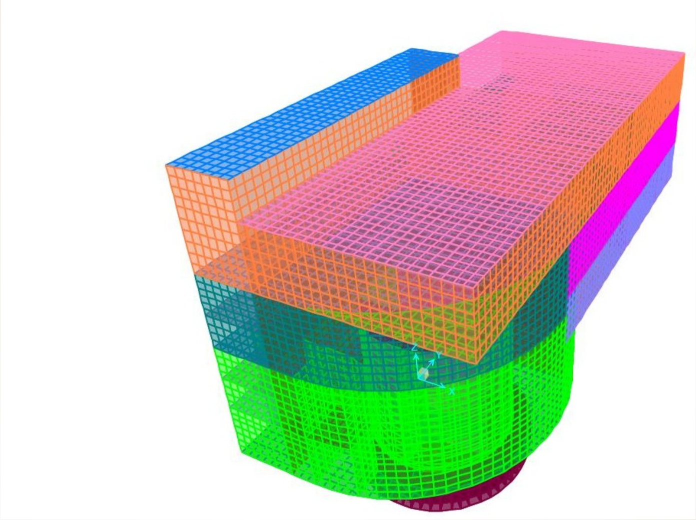
- SHAKE TH Approach
  - ✓ 30 seed THs are selected and matched to the target spectrum. All THs are statistically independent
  - ✓ Site response analysis are repeated 30 times using each of the matched time histories
- P-SHAKE RVT Approach
  - ✓ For each soil profile, one site response analysis is performed using the target spectrum as input
- RVT approach is now widely used for site response analysis in the nuclear industry

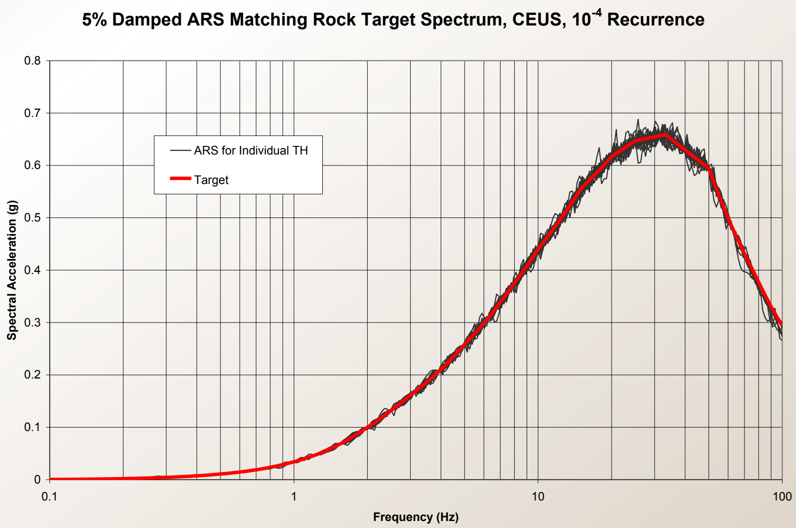


Time History Issue

Deeply embedded nuclear structure

30 time histories matched to the design response spectrum

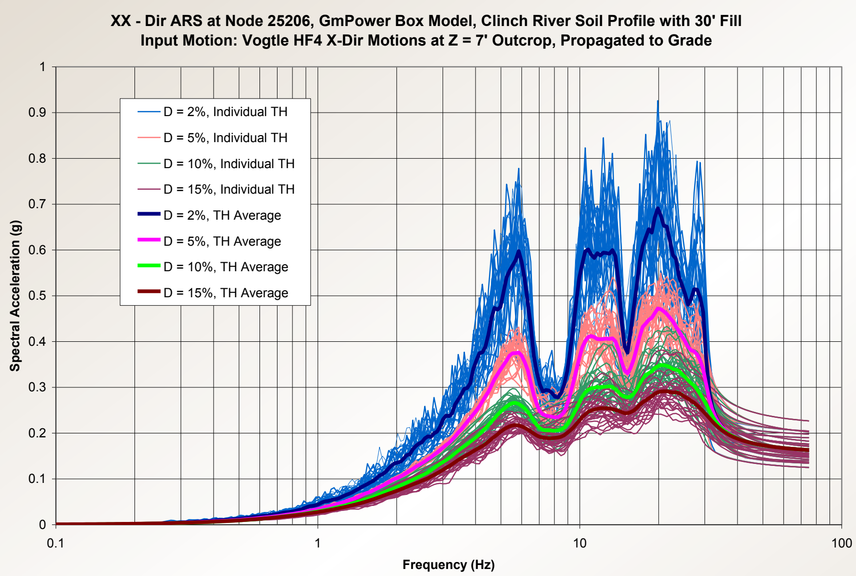


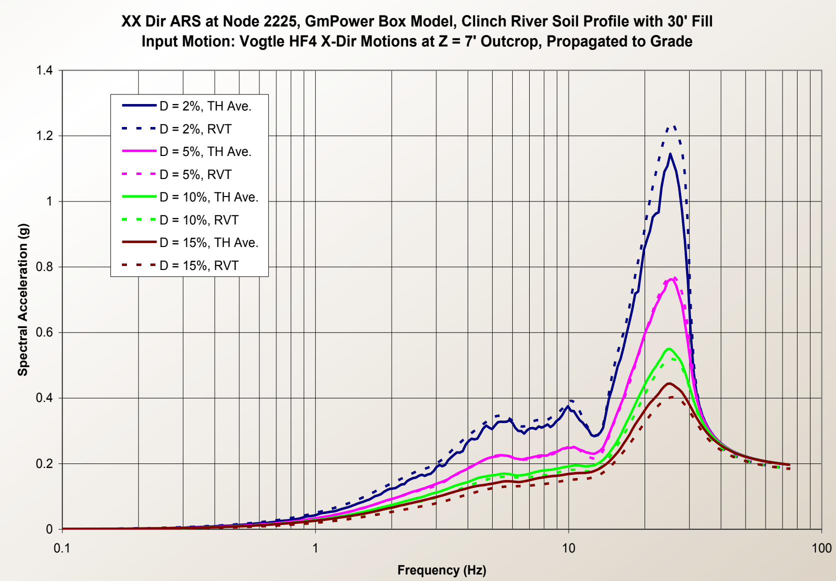


Time History Issue

Range of time history results

RVT





Time History Issue

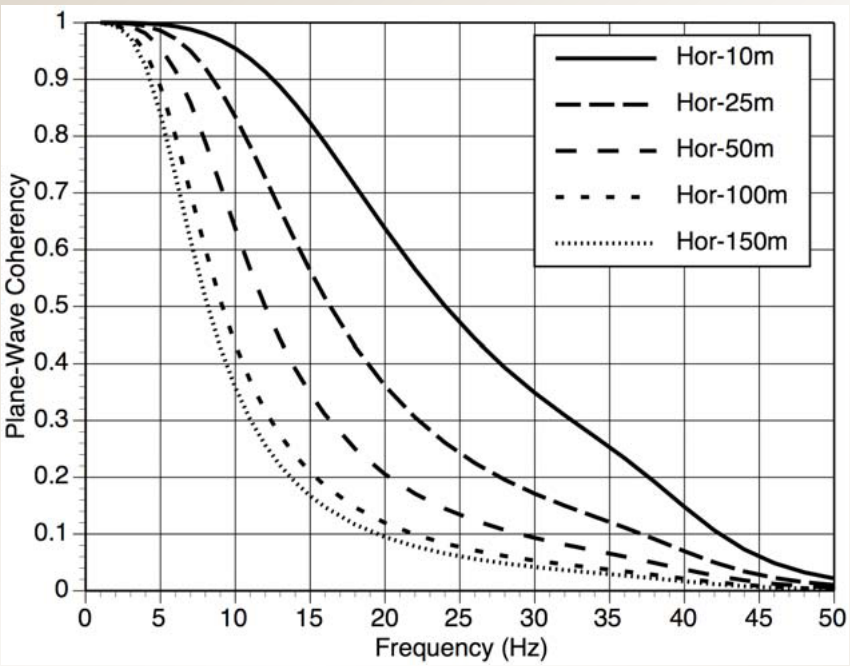
- The new ASCE 4-2015 recommends to use at least 5 time histories for SSI analysis
- The new SRP 3.7.1 Rev 4 requires PSD check on the time history in addition to spectral matching requirements
- RVT can resolve many of the time history issues

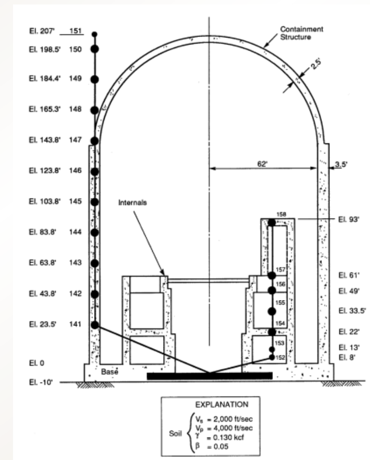
Incoherency- Research Need

- EPRI report 1015110, December 2007 (Norman Abrahamson)
- The model developed based on recorded motion for rock sites was accepted by NRC and ASCE 4 committee
- Implementation of the model in SASSI and CLASSI was approved by NRC
- Currently the model is used for SSI analysis of NPP on firm or rock sites with CEUS design motion

BECHTEL

Incoherency- Research Need





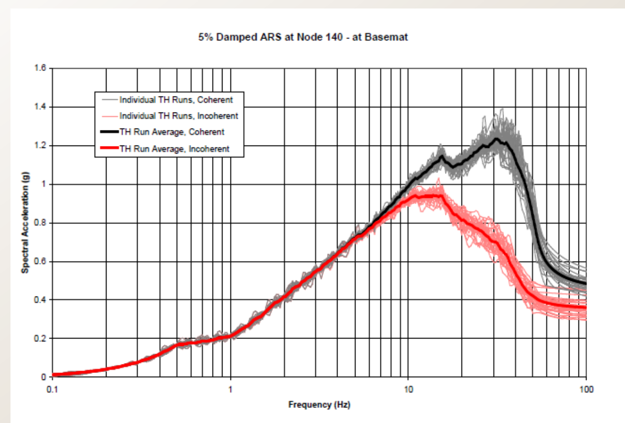


Figure 4.6–87. 5% Damped ARS at Basemat by TH Method

Incoherency- Research Need

- The ground motion model is based on recorded data, need to address incoherency in vertical direction
- NRC has limited the reduction at high frequency to 30%
- Need recorded motions on basemat of various sizes for calibration
- Ideal condition: rock or firm soil sites, high frequency ground motion

Challenges for Nonlinear SSI Analysis

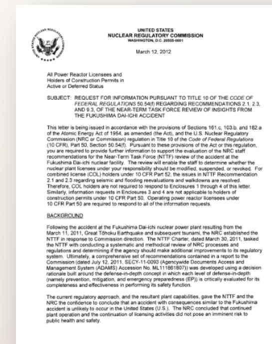
- SASSI is a linear program and is using equivalent linear analysis to handle soil nonlinearity
- NPP sites are competent sites(static foundation pressure ranges from 10 KSF to 20 KSF)
- Sites with liquefaction potential are avoided
- Large soil nonlinearity is not expected
- Nonlinearity becomes important at the soil-foundation interface for beyond design events

Challenges for Nonlinear SSI Analysis

- SASSI is a linear program and is using equivalent linear analysis to handle soil nonlinearity
- NPP sites are competent sites(static foundation pressure ranges from 10 KSF to 20 KSF)
- Sites with liquefaction potential are avoided
- Large soil nonlinearity is not expected
- Nonlinearity becomes important at the soil-foundation interface for beyond design events

Seismic Hazard and Risk Reevaluation for all Operating Plants (about 104)

- Following the Fukushima event in 2011 and recommendation of the NFFT task force, US NRC 50.54(f) Request for Information Letter Issued in March 12, 2012
- Requested specific deliverables and process
  - ✓Hazard evaluation information
  - ✓Risk evaluation information (if necessary)
  - ✓Spent fuel pool analysis



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 12, 2012

All Power Reactor Licensees and
Holders of Construction Permits in
Active or Deferred Status

SUBJECT: REQUEST FOR INFORMATION PURSUANT TO TITLE 10 OF THE *CODE OF FEDERAL REGULATIONS* 50.54(f) REGARDING RECOMMENDATIONS 2.1, 2.3, AND 9.3, OF THE NEAR-TERM TASK FORCE REVIEW OF INSIGHTS FROM THE FUKUSHIMA DAI-ICHI ACCIDENT

This letter is being issued in accordance with the provisions of Sections 161.c, 103.b, and 182.a of the Atomic Energy Act of 1954, as amended (the Act), and the U.S. Nuclear Regulatory Commission (NRC or Commission) regulation in Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, Section 50.54(f). Pursuant to these provisions of the Act or this regulation, you are required to provide further information to support the evaluation of the NRC staff recommendations for the Near-Term Task Force (NTTF) review of the accident at the Fukushima Dai-ichi nuclear facility. The review will enable the staff to determine whether the nuclear plant licenses under your responsibility should be modified, suspended, or revoked. For combined license (COL) holders under 10 CFR Part 52, the issues in NTTF Recommendation 2.1 and 2.3 regarding seismic and flooding reevaluations and walkdowns are resolved. Therefore, COL holders are not required to respond to Enclosures 1 through 4 of this letter. Similarly, information requests in Enclosures 3 and 4 are not applicable to holders of construction permits under 10 CFR Part 50. Operating power reactor licensees under 10 CFR Part 50 are required to respond to all of the information requests.

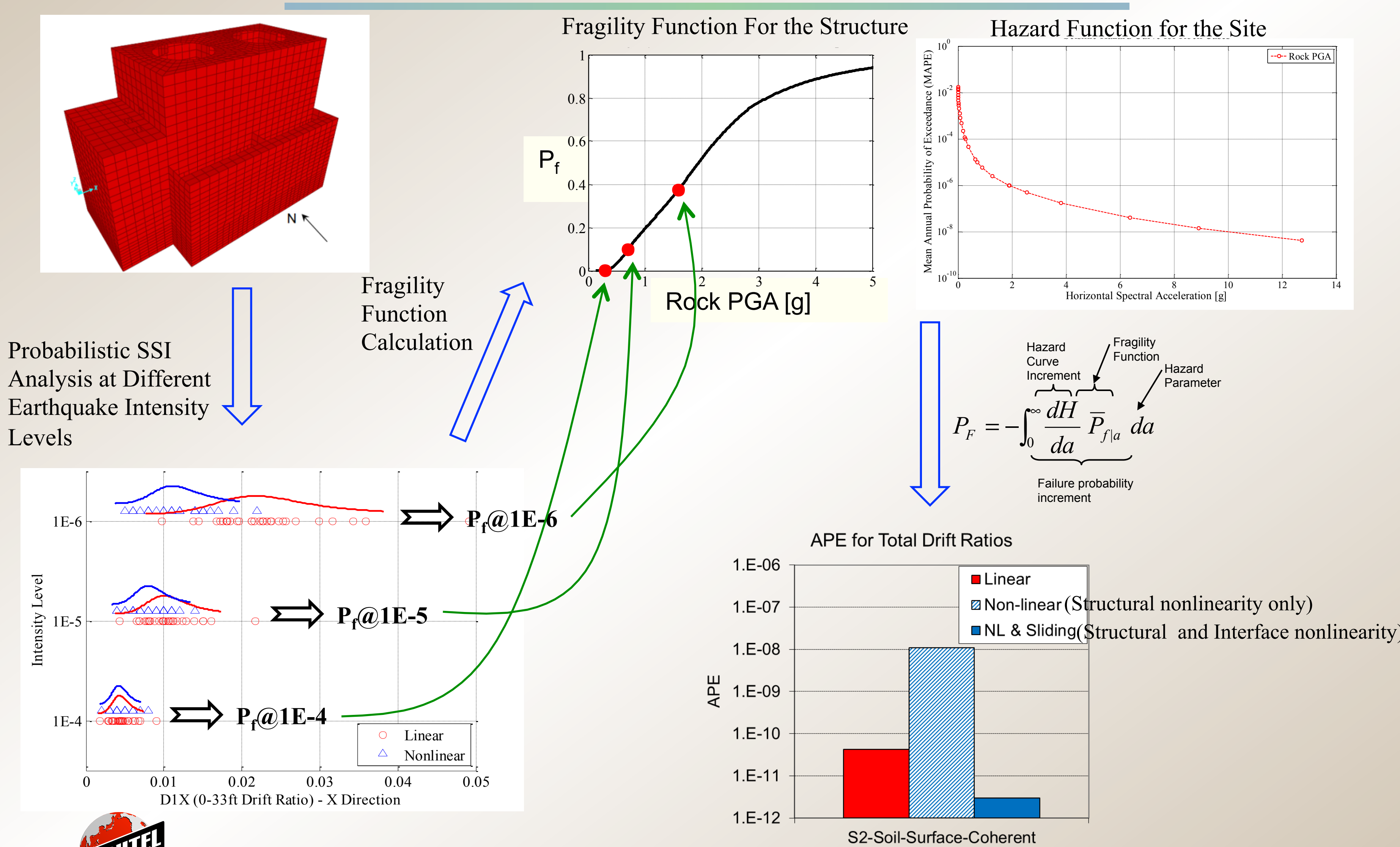
BACKGROUND

Following the accident at the Fukushima Dai-ichi nuclear power plant resulting from the March 11, 2011, Great Tōhoku Earthquake and subsequent tsunami, the NRC established the NTTF in response to Commission direction. The NTTF Charter, dated March 30, 2011, tasked the NTTF with conducting a systematic and methodical review of NRC processes and regulations and determining if the agency should make additional improvements to its regulatory system. Ultimately, a comprehensive set of recommendations contained in a report to the Commission (dated July 12, 2011, SECY-11-0093 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML111861807)) was developed using a decision rationale built around the defense-in-depth concept in which each level of defense-in-depth (namely prevention, mitigation, and emergency preparedness (EP)) is critically evaluated for its completeness and effectiveness in performing its safety function.

The current regulatory approach, and the resultant plant capabilities, gave the NTTF and the NRC the confidence to conclude that an accident with consequences similar to the Fukushima accident is unlikely to occur in the United States (U.S.). The NRC concluded that continued plant operation and the continuation of licensing activities did not pose an imminent risk to public health and safety.

- All operating plants in CEUS have submitted the new ground motion at their sites in March 2014, about 2/3 are performing SPRA now
- The 3 plants in WUS are submitting the ground motion in March 2015

Soil-Structure Interface Modeling



$$P_F = -\int_0^{\infty} \frac{dH}{da} \overline{P}_{f|a} \, da$$

Soil-Structure Interface Modeling

Need development in the following areas for a more realistic modeling of the interface condition for beyond design events:

- Test data for modeling interface sliding behavior under static and dynamic loads (stiffness and damping)
- Test data for modeling interface condition for embedded structures
- Test data for uplift behavior and subsequent impact load

Wave Field for Deeply Embedded Structures

- Current NPP designs have shallow embedment (40 ft) and foundation pressures ranging from 10 ksf to 20 ksf
- Seismic SSI results are controlled by the inertia effects
- The vertically propagation (SV and P) for SSI analysis is generally adequate for design
- New designs for modular reactors are deeply embedded (70 ft to 150 ft)
- The foundation pressure is in the range 4 ksf to 6 ksf

Wave Field for Deeply Embedded Structures

- For deeply embedded structures, kinematic interaction controls the response
- Ground motion and its variation over the embedment depth is much more important
- The opportunity for inclined waves to become vertical (Snell's law) is reduced with deeper embedment depth
- Choice of wave fields also play a significant role in the kinematic effects

Wave Field for Deeply Embedded Structures

Areas for development:

- More realistic assessment of the wave field (numerical modeling of source to site)
- Definition of the input motion (control point, control motion) and checking adequacy of the input motion for SSI analysis
- NRC adopted a revision to the current criteria for SSI analysis for deeply embedded structures to control the ground motion within the embedment depth of the structure

Thank You

Comments/Questions