Workshop on Using The NEES Equipment Site Facilities in ESG Research, International Collaborations, and Future Needs

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Panel Discussion

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- *Are we making the right observations to improve our ability to simulate site response behavior?*
- *What types of sites are lacking in observations?*
- *What are the important geotechnical site characterization parameters needed to simulate and predict site response behavior?*
- *Advantages and disadvantages to the various methods for computing site response behavior especially at large strain levels?*

NCHRP SYNTHESIS 20-05/TOPIC 42-03

PRACTICE AND PROCEDURES FOR SITE-SPECIFIC EVALUATION OF EARTHQUAKE GROUND MOTIONS

DRAFT REPORT

N. MATASOVIC AND Y. M.A. HASHASH

- Detailed literature review
- Survey of users
- Recommendations

NCHRP 20-05/42-03 - RECOMMENDATIONS

- Benchmarking of One-Dimensional of Site Response Analysis with Porewater Pressure Generation
- Threshold for Equivalent-Linear versus Nonlinear Site Response Analysis
- Input Ground Motion Selection
- Implied Strength in Modulus Reduction Curves
- Benchmarking of Multi-Dimensional Total and Effective-Stress Site Response Software
- Benchmarking of Vs Correlations and Evaluation
- Evaluation of Liquefaction from Site Response Analysis
- Site Response in Deep Deposits
- Vertical Site Response Evaluation
- Calibration of Nonlinear Site Response Analysis from Recent Japan Earthquake

NCHRP 20-05/42-03 - RECOMMENDATIONS

- Benchmarking of One-Dimensional of Site Response Analysis with Porewater Pressure Generation
  - A landmark benchmarking project was performed in 2006/2007 by PEER (Kwok, et al. 2007).
  - Given the importance of use on nonlinear effective-stress analysis for site class E (soft soils) and Site Class F (liquefiable soils and very soft clays in the profile), and its gradual increase in use, we believe that a rigorous benchmarking study of one-dimensional nonlinear software with porewater pressure generation is warranted and should be conducted

NCHRP 20-05/42-03 - RECOMMENDATIONS

- Benchmarking of Vs Correlations and Evaluation
  - The study would also identify available Vs measurement tools and the relative merits of various Vs measurements including downhole, sCPT, OYO suspension logging, ReMi, SASW, and MASW.
  - Given the importance of Vs profile in site response analysis, we believe that a systematic study of Vs –SPT and other correlations (e.g., Vs – qc and Vs – Su) should be undertaken. The work would involve comparison of shear wave velocity profiles established through correlative expressions to the results of actual measurements. The findings of such a study should clearly identify which correlations may be recommended for given site conditions (e.g., should a SPT-based correlation be used when site-specific results of Su measurements are available?) and what is a possible range of error?

NCHRP 20-05/42-03 - RECOMMENDATIONS

- Vertical Site Response Evaluation
  - In dynamic analysis of structures and SSI, three-dimensional motions are required as input. This survey has found that the overwhelming majority of work done on site response analysis is related to horizontal motion. The literature is poor on the procedure for handling the local site effects on vertical ground motion propagation. Currently, PEER has an effort focused on vertical site response as part of an update of NGA-West. A detailed study on vertical site response would be timely and fill a major gap in the body of knowledge in site response.

NCHRP 20-05/42-03 - RECOMMENDATIONS

- Calibration of Nonlinear Site Response Analysis from Recent Japan Earthquake
  - The 11 March 2011 earthquake in Japan has provided the research community with an extensive data set from multiple large events. This data set includes a significant number of downhole arrays (KiK-net) which have been excited by the main shock as well as by several large foreshocks and aftershocks. This data set provides a unique opportunity to validate and improve site response analysis models. A study that focuses on the use of this data set will be very useful for increasing the reliability of site response analysis procedures, especially for long duration earthquakes, and the proper representation of cyclic soil behavior under repeated cycles of loading that has only been studied in the laboratory.

ARE WE MAKING THE RIGHT OBSERVATIONS TO IMPROVE OUR ABILITY TO SIMULATE SITE RESPONSE BEHAVIOR?

- Tohouku EQ provides an excellent data set that needs to be explored in great detail
- We remain focused on primarily 1-D
- Need for deployable vertical arrays (e.g. aftershocks in Christchurch and Japan).

WHAT TYPES OF SITES ARE LACKING IN OBSERVATIONS?

- Soft soils, clay and liquefaction susceptible sites.

WHAT ARE THE IMPORTANT GEOTECHNICAL SITE CHARACTERIZATION PARAMETERS NEEDED TO SIMULATE AND PREDICT SITE RESPONSE BEHAVIOR?

- -Detailed Vs measurements including measurements of variability (e.g. suspension logger)
- -In situ small strain damping profile vs laboratory measured curves.

ADVANTAGES AND DISADVANTAGES TO THE VARIOUS METHODS FOR COMPUTING SITE RESPONSE BEHAVIOR ESPECIALLY AT LARGE STRAIN LEVELS?

- 1-D (e.g. DEEPSOIL, www.illinois.edu/~deepsoil, DMOD) vs 2 & 3 D methods

- Standard modulus reduction and damping curves

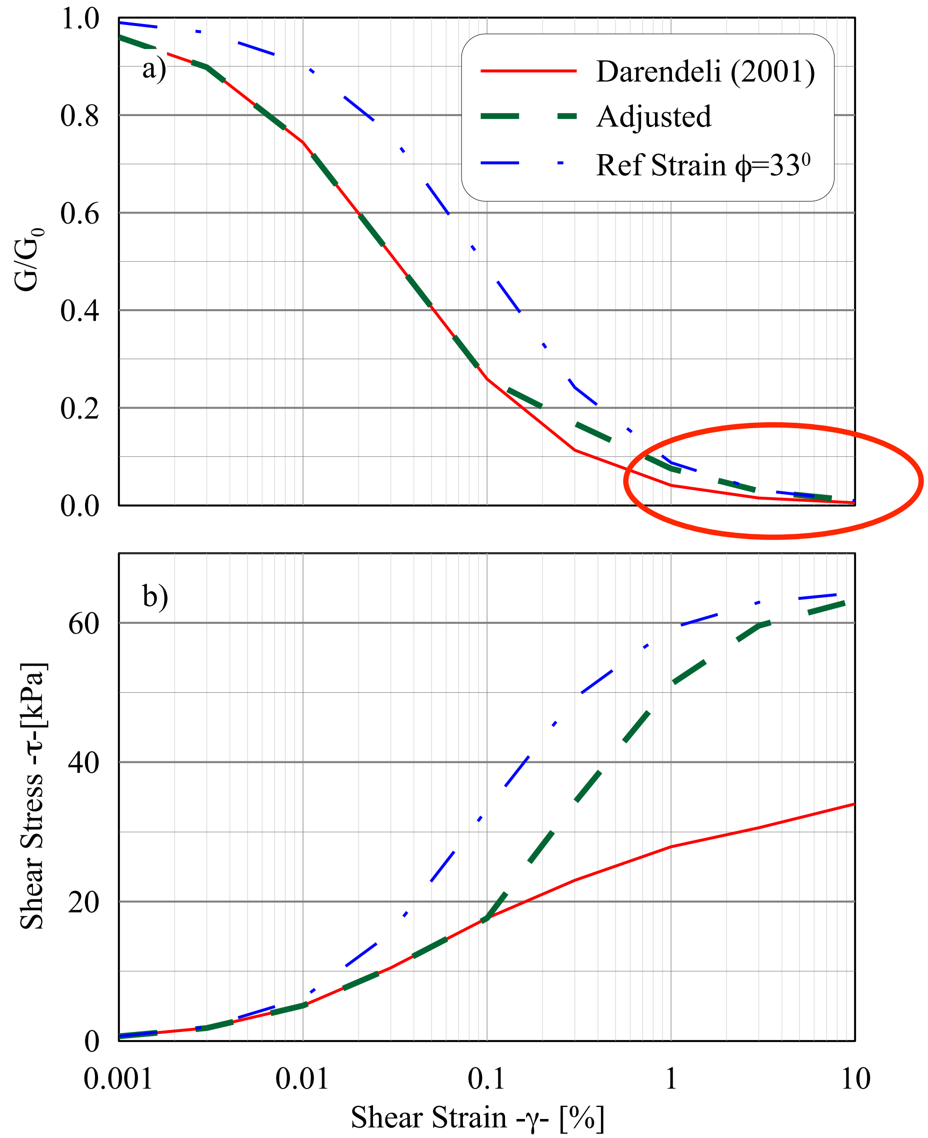
Implied Soil Strength At Large Strains

-Large strains in soft soils and due to strong shaking.

-Need for better resolution of implied strength or friction angle.

-Stewart and Kwok (2008)

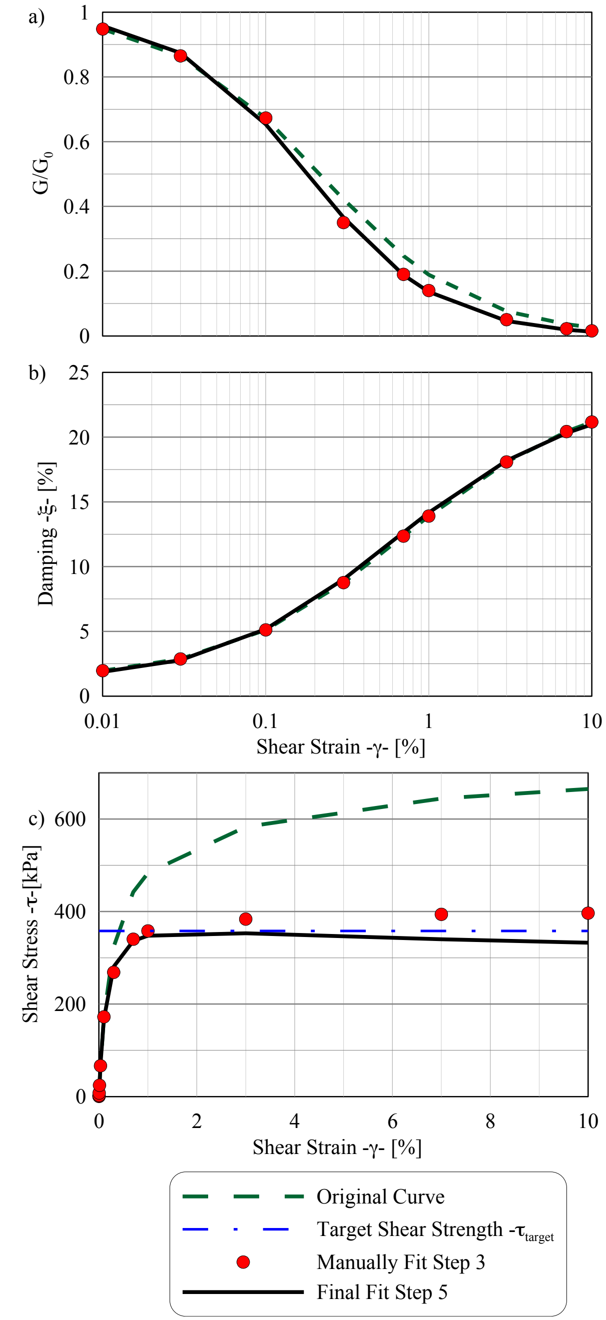
Suggested hybrid procedure for equivalent linear approach



IMPLIED SOIL STRENGTH AT LARGE STRAINS

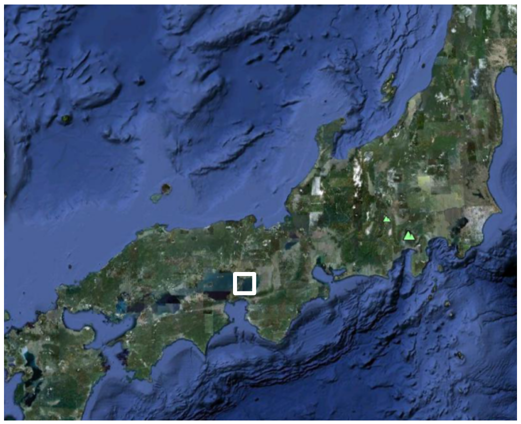
Iterative Procedure for NL backbone curve:

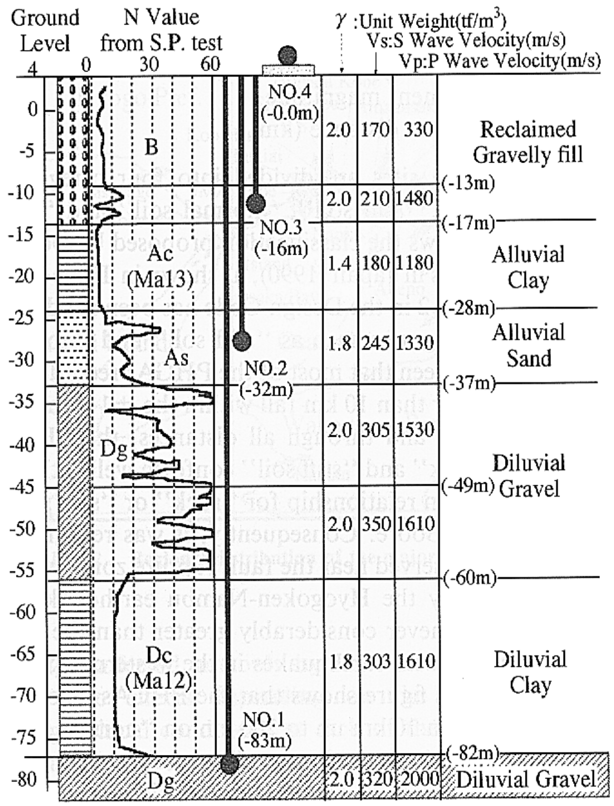
1) Fit the target using MRDF model.
2) Compute the implied soil shear strength
3) <u>Underestimation</u>: implied shear strength or friction angle is larger than the target value
   <u>Overestimation</u>: implied shear strength or friction angle is lower than the target value
4) Fit the modified modulus reduction curve (Step 3) and the damping curve obtained in Step 1 using the MRDF procedure.
5) Calculate the implied shear strength for the fitted curve using the aforementioned equations. If the implied shear strength is significantly higher or lower than the target value repeat Steps 3-5.

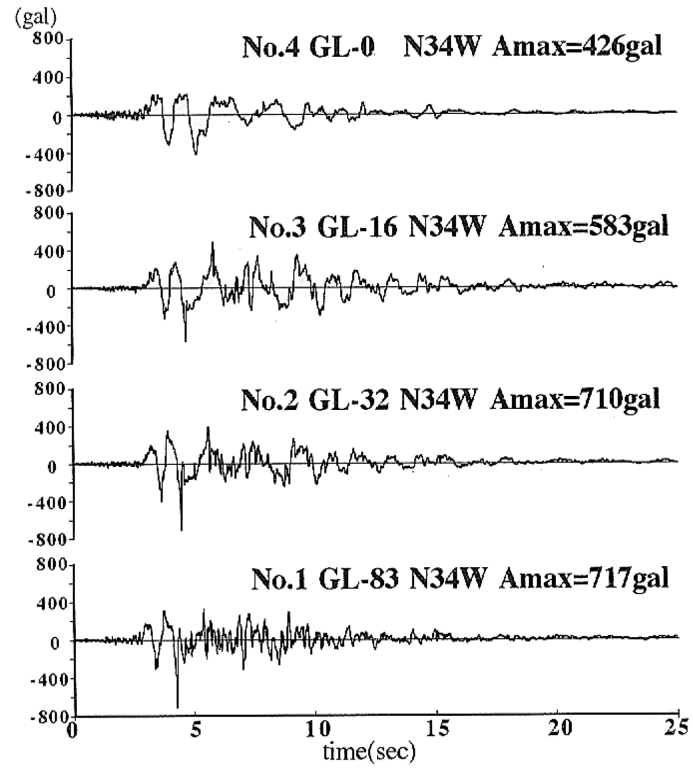


Need new functional forms and improved procedures

Field Evidence: Port Island, Kobe, 1995. Vertical Array







Soils & Foundations (1996)

MOTIVATION

Building Research Institute (BRI), Japan :

Urban Disaster Mitigation Research Center (annex) building