THIRD UJNR WORKSHOP ON
SOIL-STRUCTURE INTERACTION

Proceedings of a workshop organized under the auspices of United States-Japan Cooperative Program in Natural Resources (UJNR), March 29-30, 2004, Vallombrosa Center, Menlo Park, California

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The third UJNR workshop on Soil-Structure Interaction (SSI) was held on March 29–30, 2004, at the Vallombrosa Center, Menlo Park, California. It was attended by 56 researchers and practitioners, mostly from United States and Japan, which are the carriers of the charter of the UJNR program, but also from other countries (Greece, France, Mexico and Turkey). This workshop follows the first one held in Menlo Park, CA, September 22–23, 1998, which initiated this tradition, and facilitated the interaction between researchers in U.S. and Japan in the field, and the second one held in Tsukuba, Japan, March 6–8, 2001.

Following the continuous advances in the SSI technology since the first and second workshops, many new research results and ideas were presented at this workshop, and the number of participants increased to fifty-six. The productive discussion following the technical presentations gave a distinct orientation to the SSI research and our future activities. One lesson from the third workshop is that, in planning future workshops, more than two days are needed to provide sufficient time for both a large number of presentations and a discussion.

This proceedings presents a summary of the workshop presentations, discussion and recommendations, and a compilation of the individual contributions associated with the 43 presentations (42 technical papers and one presentation).

Finally, the Organizing Committee would like to expresses its gratitude to the National Science Foundation (NSF), the United States Geological Survey (USGS), and the National Institute for Land and Infrastructure Management (NILIM), and the Building Research Institute of Japan (BRI) for their financial and other support.

The appreciation is also extended to the participants who enthusiastically joined the discussion, and to the staff of USGS, in particular, Pauline Curiel, who arranged the logistics and the preparation of the preliminary proceedings distributed at the workshop. The organizing committee sincerely hopes that this activity of gathering and exchange of ideas and information on research and practices in the field of soil-structure interaction will continue in the future.

August 26, 2004

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ACKNOWLEDGEMENTS

This workshop could not have been possible without the financial support from U.S. National Science Foundation, via a grant to University of Southern California (CMS-0336939), U.S. Geological Survey, and Building Research Institute of Japan. The organizers would also like to express their gratitude to California Department of Transportation (CalTrans) for arranging for a visit to the Bay Bridge construction site, coordinated by Anoosh Shamshabadi, and guided by Mark Woods.
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Contributions
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SUMMARY

Background and Objectives

Soil-structure interaction is a collection of phenomena in the response of soil-foundation-structure systems that are caused by the flexibility of the foundation soil. In general, it is manifested by lengthening of the apparent system period, and modification of the foundation input motions. Progress in the understanding and modeling of this complex phenomenon is necessary for improvements of the structural design and construction practices, and, as a result, for reduction of loss of life and monetary losses caused by earthquakes.

This workshop was the third in a series, organized under the auspices of the United States–Japan Cooperative Program in Natural Resources (UJNR), a government to government program established in 1964 to promote conservation of marine and terrestrial resources through cooperation in applied science and technology. More detailed information on this program and its activities can be found at http://www.lib.noaa.gov/japan/ujnr/ujnr.html. The organization of this series of workshops has been an activity of the UJNR Panel on Wind and Seismic Effects—Committee on Strong Motion. The first two workshops were held in Menlo Park, California (September 22–23, 1998), and Tsukuba, Japan (March 6–8, 2001), and were organized by U.S. Geological Survey (USGS) of U.S. Department of the Interior and Building Research Institute (BRI) of Japan Ministry of Land, Infrastructure and Transport.

The purpose of these workshops has been to provide a platform for the experts in the field from both countries to present their work, exchange ideas, identify future research needs, and foster collaboration. Both workshops were attended by professionals from academia, government and industry, and covered the following topics: (1) current methods of soil-structure interaction and practices in U.S. and Japan – geotechnical and structural points of view, (2) code provisions and limitations, (3) observed data, (4) observational arrays and testing facilities, (5) recent research results on how to implement those into practice, (6) additional research needs, and (7) additional observational arrays and testing facilities needed. An additional objective of this (third) workshop was to introduce the two major experimental and seismic monitoring initiatives in the U.S.—Network of Earthquake Engineering Simulation (NEES) and Advanced National Seismic System (ANSS), and the opportunities for research in soil-structure interaction they could provide.

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Financial support for this workshop was provided by U.S. National Science Foundation (NSF), via a grant administered by the University of Southern California, U.S. Geological Survey, and Building Research Institute of Japan.

Participants

The soil-structure interaction is a complex problem at the intersection of three disciplines: Structural Engineering, Geotechnical Engineering, and Engineering Seismology, that are usually compartmentalized both in the educational system and in practice. The participants of this workshop included representatives from all of these three professional communities, and from academia, industry and government labs and agencies. Total of 56 participants attended the workshop: 33 from U.S. (including 8 graduate students), 19 from Japan, and 4 from other countries—Mexico, Greece, France and Turkey.

Field Trip

A field trip was arranged to the Bay Bridge construction site, selected instrumented buildings in San Francisco, and to the Golden Gate bridge prior to the workshop. The organizers are most grateful to the CalTrans staff, in particular to Anoosh Shamshabadi, for providing access to the Bay Bridge construction site and for the interesting presentations.

Technical Program

Total of 43 papers were presented, organized in three plenary sessions and four technical sessions. The plenary speakers, M. Iguchi, J.E. Luco and G. Gazetas, presented:

- Michio Iguchi: “Observations versus analyses: lateral earth pressures on an embedded foundation during earthquakes and forced vibration tests,” by Michio Iguchi, and Chikahiro Minowa;
- J.E. Luco: “Forced vibration tests of the foundation block and surrounding soil at the NEES/UCSD large high-performance shake table,” by J.E. Luco, J.P. Conte, B. Moaveni, L. Mendoza, and D. Whang; and

The other presentations were organized in five groups/technical sessions:

- Earthquake observations and analyses (10 talks);
- Opportunities for research via NEES (Network for Earthquake Engineering Simulations) and ANSS (Advanced National Seismic System)— major experimental and seismic monitoring initiatives in the U.S. since the previous workshop (6 talks);
- Design issues and seismic performance (5 talks, two of which dealt with proposals for implementations in design);
- Analytical modeling and numerical simulations and analyses (11 talks); and
- Experimental methods and analyses (8 talks).
The technical sessions were followed by a session on Discussion and Recommendations, moderated by J.E. Luco and S. Mori. The following two sections summarize the discussion and recommendations.

**Discussion and Recommendations**

The discussion was organized around the following topics.

- **Experimentation**: In the period between the two workshops, there has been a significant expansion of experimental facilities and seismic monitoring programs in the U.S. and Japan (for example, NEES and ANSS initiatives). The large number of papers presented at the workshop on analysis of experimental data and the expected output of the new facilities suggest that a wealth of experimental information will be created that will need to be managed for optimum dissemination. A minimum objective of the UJNR program should include the cataloging of the experimental data available on soil-structure interaction. The creation of a repository of the data in a format compatible with post-processing software and visualization programs is highly recommended. A policy of data sharing also needs to be developed.

- **Analysis**: The papers at the workshop indicate continued analytical advances in the modeling of nonlinear SSI, on the incorporation of uncertainty in material properties and loads, and on the study of the effects of topography and of the built environment.

- **Design**: Some promising initial efforts to incorporate the effects of SSI on design codes were reported at the workshop. It is important that these efforts continue.

- **Collaboration**: The professional communities need ways to communicate more effectively between workshops, including sharing data and organization of joint experiments. Dr. Minowa invited all interested participants to collaborate in the planned large-scale SSI shaking table tests using the E-Defense shake table in Miki City, Japan.

**Recommendations**

*Experiments and Observations*

- The number of both laboratory and field experiments conducted are in general insufficient. The new NEES experimental facilities (presented at this workshop) will be a significant addition to current capabilities for SSI research in the U.S.

- Prototype seismic observation systems that are aimed to yield SSI-related data are also insufficient. However, there are a few recent instrumented structures (both in the United States and Japan) that include additional instrumentation to capture SSI effects.

- It is desirable that when an SSI related experiment is planned, the design of the experiment be communicated to the SSI research community for possible participation and collaboration.

- More experimental and analytical research on dynamic soil-pile-structure interaction is needed for short period structures on soil that will liquefy during strong shaking. The key issues to be addressed are:
  - the extent of pile-group effects,
  - how to model these effects when there are a large number of closely spaced piles,
  - kinematic vs inertial SSI effects,
  - the extent of load reduction on the superstructure as a result of SSI. More, and different types of structures are being designed and constructed on potentially

Summary—3
liquefiable soils, so this recommendation is timely. The current SSI provisions in codes do not adequately cover this situation, if at all.

**Analyses and Design Issues**

- Professor E. Luco urged SSI research community to get more involved in design recommendations and provide scientifically justified but practical input to increase the safety of design codes.
- Comparative studies between the two countries and other countries should be encouraged.
- Research in allowance, controlling or utilization of various types of foundation failure should be conducted.

**Dissemination of Research Results, Data Sharing and Data Management**

- The collection and organization in a database of experimental and seismic monitoring data on soil-structure interaction phenomena is a much needed and realizable objective of the SSI research community.
- An similar collection/database of analytical results should also be organized. Such a collection would be an invaluable resource to optimize computational and analytical efforts, as well as design of experiments and interpretation of laboratory and seismic monitoring data.
- Developing a mechanism in Japan for sharing data is very much needed. While data is openly available in U.S., that is not the case in Japan.
- Professor Maria Todorovska volunteered to expand the Workshop web site (residing on USC web) to serve as an information resource for the SSI community. The site would include links to individual participants web sites, where participants would post data and research results they wish to share. Links to other relevant sites in U.S., Japan, and other countries will be added.
- Professor Fukuwa has already developed such a web site for Japan, with a portal web site (on BRI web) through which all the sites in Japan can be accessed. The future U.S. site will be linked to this portal site.

**Education and Outreach**

- Good textbooks on SSI and software for educational use are very much needed. Such a textbook was published in Japan (Iguchi et al.) as presented at the 1st UJNR Workshop, but was found to be too difficult, and a 2nd simplified edition is being prepared (Fukuwa et al.).
- Incorporation of courses on SSI effect in the curriculum of colleges and universities is needed, as well as short courses for practicing engineers.
- The research community should be more active in outreach and advertise new software development to potential users.
- Development of computer software for educational use is needed.
Recommended Research Areas

- Research on estimation of SSI effects from seismic/ambient monitoring and from experimental data should be continued.
- Dense seismic monitoring arrays should be further deployed in and around man-made structures to provide high quality data on SSI effects during future large earthquakes.
- Practical use of microtremor (ambient measurement) should be investigated
- Theoretical studies on SSI should address:
  - Nonlinear effects (material and geometric nonlinearities), finite deformation theory and more realistic assumptions.
  - Comparative studies and validation with observed data.
  - Development of practical simplified procedure to evaluate the SSI effect
  - Quantification of uncertainty, e.g. in the soil properties and its effects.

Future Collaboration

- In the United States, a committee similar to the one in Japan needs be formed, possibly under the auspices of UJNR (e.g. a subcommittee of Panel on Wind and Seismic Effects). Such a committee can meet periodically between workshops to plan activities and would be involved in promoting research and education in SSI and facilitating collaborations.
- Exchange of scientists and engineers between US and Japan to conduct SSI research should be encouraged, in particular, for collaboration in planning and use of the experimental facilities.

Next Meeting

- Next UJNR meeting is planned to be in Japan (Kyoto or Kobe City) in 2-3 years.
RESOLUTION

Whereas soil-structure interaction can have major influence on the seismic performance of important structures, such as buildings, dams, bridges, and nuclear power plants, and thus affect public safety; and

Whereas, the methodologies for including soil-structure interaction effects in assessing seismic performance of such structures, although improving, are still inadequate; and

Whereas, present-day design codes need to provide more definitive guidance for treating soil-structure interaction effects;

Whereas, the recent devastating earthquake experiences gave us valuable knowledge and data for us to share.

Now therefore be it resolved that

(1) research to advance soil-structure interaction methodologies be maintained at high priority and that design provisions related thereto be incorporated into the codes to enhance the seismic safety of structures designed accordingly, and
(2) cooperation between the U.S. and Japan, with focus on advancing both state-of-the art and state-of-the-practice of treating soil-structure interaction be continued, and
(3) future additional UJNR-SSI meetings to be organized, and
(4) carryout future activities under current UJNR framework and pursue establishment of an international organization to promote advance research, education, and design practice as related to soil-structure interaction.

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Menlo Park, CA, March 29-30, 2004
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Group photo: Third UJNR Workshop on Soil-Structure Interaction, March 29-30, 2004, Vallombrosa Center, Menlo Park, California
PROGRAM

Sunday, March 28, 2004

12:00- Check in
5:00- 6:00 pm Icebreaker Reception
6:00- 7:00 Dinner

Monday, March 29, 2004

7:00-  8:00 am Breakfast
7:30-  Registration
8:15-  8:20  Opening Remarks
Mehmet Celebi and Izuru Okawa
8:20-  9:00  Plenary Talk I
Michio Iguchi: Observations versus analyses of lateral earth pressures on an embedded foundation during earthquakes and forced vibration
9:00-12:00 Technical Session I
Earthquake Observations and Analyses (9 talks)
Chairs: Izuru Okawa and Javier Avilés
12:00-  1:00 pm Lunch
1:00-  1:40 Plenary Talk II
J.E. Luco: Forced vibration tests of the foundation block and surrounding soil at the NEES/UCSD large high-performance shake table
1:40-  3:10  Technical Session II
Opportunities for Research via NEES and ANSS (5 talks)
Chairs: J. Enrique Luco and Jonathan Stewart
3:10-  3:40 Break
3:40-  5:30  Technical Session III
Design Issues and Seismic Performance (6 talks)
Chairs: Yoshihiro Sugimura and C.B. Crouse
6:15- Transportation to Vaso Azzurro Ristorante
7:00-  9:30 Banquette dinner at Vaso Azzurro Ristorante
9:30- Transportation back to Vallombrosa Center
Tuesday, March 30, 2004

7:00- 8:00 am  Breakfast
8:00- 8:40 Plenary Talk III
   George Gazetas:  Nonlinear soil-structure interaction: foundation uplifting and soil yielding
8:40-12:00 Technical Session IV
   Analytical Modeling and Numerical Simulations and Analyses (10 talks)
   Chairs: Eduardo Kausel and Kazuhiro Yoshida
1:00- 3:05 pm Technical Session V
   Experimental Methods and Analyses (10 talks)
   Chairs: Annalingam Anandarajah and Masanori Iiba
3:30- 5:30 Discussion and Recommendations
   Closure
6:00- 7:00 Dinner

Wednesday, March 31, 2004

7:00- 8:00 am  Breakfast
                Adjourn
CONTRIBUTIONS

The technical program of the workshop included 43 presentations, organized in three plenary sessions and four technical sessions. Electronic files of the contributions (42 technical papers and a handout of one presentation) can be accessed by clicking on the icon in the title line of the particular contribution. The name of the presenting author is underlined.

I: State of the Art Talks

• Observations versus analyses: lateral earth pressures on an embedded foundation during earthquakes and forced vibration tests, by Michio Iguchi and Chikahiro Minowa.
• Forced vibration tests of the foundation block and surrounding soil at the NEES/UCSD large high-performance shake table, by J.E. Luco, J.P. Conte, B. Moaveni, L. Mendoza, and D. Whang.
• Nonlinear soil-structure interaction: foundation uplifting and soil yielding, by George Gazetas and Marios Apostolou.

II: Earthquake Observations and Analyses

• Seismic observation systems in Nagoya University and publication of data, by Nobuo Fukuwa, Jun Tobita, and Hiroaki Kojima.
• Soil-structure interaction effects on building response in recent earthquakes, by Yasuhiro Hayashi and Ikuo Takahashi.
• Dynamic soil-structure interaction in low-rise buildings from seismic records, by Madan B. Karkee, Kazuya Mitsuji, and Yoshihiro Sugimura.
• Dynamic behavior of a 9-story base-isolated building during the 2003 off Tokachi earthquake, Japan, by Toshihide Kashima, Akihiro Itou and Hisashi Fujita.
• Study on distribution of first natural period (T1) and its amplification factor derived from response and limit strength calculation for subsurface soil layers, by Shin Koyama.
• Soil-structure interaction and site response at the Jensen Filtration Plant during the 1994 Northridge, California, mainshock and aftershocks, by C.B. Crouse and Juan Carlos Ramirez. (included in this proceedings with permission from the Seismological Society of America).
• Ground motions with static displacement derived from strong-motion accelerogram records by a new baseline correction method, by Nobuyoshi Yamaguchi, Ilker Kazaz and Chikahiro Minowa.
• Two recent strong motion records from Turkey: re-interpretation of Bolu (1999) and Býngöl (2003) seismograms, by Polat Gulkan and Sinan Akkar.
• Strong motion recording for buildings in Japan, by Izuru Okawa, Toshihide Kashima, Kuniaki Yamagishi, and Morimasa Watakabe.

• Variability of soil-structure system frequencies during strong earthquake shaking for a group of buildings in Los Angeles estimated from strong motion records, by Maria I. Todorovska, Tzong-Ying Hao, and Mihailo D. Trifunac.

III: Opportunities for Research via NEES and ANSS

• Ground motion, pore water pressure and SFSI monitoring at NEES permanently instrumented field sites, by T. L. Youd, J. H. Steidl, and R. L. Nigbor.

• Field testing capabilities of the nees@UCLA equipment site for soil-structure interaction applications, by Jonathan P. Stewart, Daniel H. Whang and John W. Wallace.

• A brief overview of the NEESGrid simulation platform OpenSees: application to the soil–foundation–structure interaction problems, by Boris Jeremić.

• Large-displacement facility for testing of highly ductile lifeline systems, by Scott L. Jones, Keith E. Kesner, Thomas D. O’Rourke, Harry E. Stewart, Tarek Abdoun, and Michael J. O’Rourke.

• The promise of NEES research, by Steven McCabe (NSF).

• Opportunities for soil-structure interaction research via ANSS, by Mehmet Celebi and Janise Rodgers.

IV: Design Issues and Seismic Performance

• Design concepts for yielding structures on flexible foundation, by Javier Avilés and Luis E. Pérez-Rocha.

• Seismic design of a structure supported on pile foundation considering dynamic soil-structure interaction, by Yuji Miyamoto, Katsuichiro Hijiwata and Hideo Tanaka.

• Implementation of soil-structure interaction models in performance based design procedures, by Jonathan P. Stewart, Craig Comartin, and Jack P. Moehle.

• Design and actual performance of a super high R/C smokestack on soft ground, by Shinichiro Mori.

• An investigation on aspects of damage to precast concrete piles due to the 1995 Hyogoken-Nambu earthquake, by Yoshihiro Sugimura, Madan B. Karkee, and Kazuya Mitsuji.

V: Analytical Modeling and Numerical Simulations and Analyses

• Effects of contact condition of side walls of embedded foundation on dynamic response of structures, by Kazuhiro Yoshida and Tetsuya Hagiwara.

• Finite element formulation of poro-elasticity suitable for large deformation dynamic analysis, by Ronaldo Borja, and Chao Li.
• Numerical treatment of wave propagation in layered media, by Murthy N. Guddati, Si-Hwan Park and John L. Tassoulas.

• Interaction between earthquake ground motion and multiple buildings in urban regions, by Antonio Fernández-Ares and Jacobo Bielak.

• Strong motion site effects in the Athens, 1999 earthquake, by Dominic Assimaki and Eduardo Kausel.

• Estimating total system damping for soil-structure interaction systems, by Farhang Ostadan, Nan Deng and Jose M. Roesset.

• A simplified method for dynamic response analysis of soil-pile-building interaction system in large strain levels of soils – analysis for building with embedment and pile, by Shin’ichiro Tamori, Masanori Iiba, and Yoshikazu Kitagawa.

• Simulation of soil-structure interaction effects by discrete-time recursive filters, by Erdal Şafak.

• Soil spatial variability effect on soil structure interaction studies: enveloping uncertainties in structural response, by Nicholas Simos, and Carl Costantino.

• Seismic motion incoherency effects on structure, by Dan M. Ghiocel and Letian Wang.

• Approximate external boundaries for truncated models of unbounded media, by J. Enrique Luco.

VI: Experimental Methods and Analyses

• Experimental study on nonlinear soil structure interaction of nuclear power plants using large scale blast excitations, by Osamu Kontani, Atsushi Suzuki, Yoshio Kitada, and Michio Iguchi.


• Study on the dynamic characteristics of an actual large size wall foundation by experiments and analyses, by Masanobu Tohdo.

• Field method for estimating soil parameters for nonlinear dynamic analysis of single piles, by A. Anandarajah, J. Zhang and C. Ealy.

• Soil profile confirmation through microtremor observation, by Yuzuru Yasui and Tatsuya Noguchi.

• Evidence of soil-structure interaction from ambient vibrations—consequences on design spectra, by F. Dunand, P.-Y. Bard, J.-L. Chatelan, and Ph. Guéguen.

• Effects of soil-structure interaction at an earthquake observation station identified by microtremor measurement, by Toshiro Maeda.

• A study on dynamic soil-structure interaction effect based on microtremor measurement of building and surrounding ground surface, by Masanori Iiba, Morimasa, Watakabe Atsushi Fujii, Shin Koyama, Shigeki Sakai, and Koichi Morita.
CONTRIBUTIONS