Summary of Workshop Discussions and Workshop Recommendations

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INTRODUCTION

The workshop was structured on three topical sessions. Each session had the format of invited state-of-knowledge presentations followed by an open discussion by all workshop participants aimed at developing recommendations. The following summarizes the workshop discussions and recommendations.

GUIDELINES FOR GEOTECHNICAL STRONG-MOTION ARRAY SITE SELECTION

The Session 1 invited presentations and subsequent discussion raised a number of important points regarding not only priorities for selection and instrumentation of new geotechnical strong-motion array sites, but also regarding the problem of integrated oversight of arrays in the United States to enhance their contributions to earthquake engineering.

Site Selection

There is currently in the United States no general review organization for geotechnical arrays that would periodically evaluate the relevance of the current installations, suggest new or modified arrays and identify 'targets of opportunity' to be instrumented (e.g., bridges and new public buildings in the planning stage). An ideal national program review panel would include representatives from both public and private sectors, including researchers and practitioners, meeting on a regular basis to review the current site inventory and discuss new installations. Topics for discussion would include current relevance of the site, new instrumentation, level of site characterization and accessibility of all information. The organization of such a group, under the auspices of one or more organizations dedicated to earthquake research (e.g., the Earthquake Engineering Research Institute, Seismological Society of America, COSMOS) should be a high priority for the earthquake engineering community.

With regard to the types of sites to be chosen, there seemed to be general agreement with the suggestion [1] that more detailed observations of soil-foundation-structure interaction should have a high priority. For instrumentation of soil/structure systems in general, it was pointed out that a major 'selling point' for the structures' owners would be the usefulness of these arrays in structural health monitoring and decision support regarding the viability of the structure after a major event.

Two types of structures were proposed:

1. A pile-supported building of modern design. This building should be in a deep, soft non-liquefiable deposit and supported by long piles. The building, the piles and the underlying soil should be thoroughly instrumented as a joint effort by structural and geotechnical engineers. The installation should be complemented by one or more free-field arrays. A public building surrounded by permanent open space seems to be the best choice.
2. Pile-supported wharf structures in liquefiable soils. In this case it would be desirable to instrument two structures, one in improved ground and one in unimproved shore deposits or artificial fill.

For new 'free-field' type sites in liquefiable soils, priority should be given to locations susceptible to significant lateral spreading, instrumented to capture post-liquefaction behavior. Both sites in loose contractive sands and in medium-dense materials capable of exhibiting dilation at large strains should be considered. At least one site with an impervious 'cap' layer of low permeability would be desirable.

Site Characterization

The level of site characterization required to provide the parameters necessary for modeling site response was extensively discussed in Workshop 1 of this series, and is summarized in the paper by de Alba for this meeting. Suggested characterization methods were based on conventional field and laboratory tests. This level of site characterization, in combination with dense instrumentation arrays (see below) should provide the information necessary to validate state-of-the art soil models. There seemed to be agreement among the participants that soil models which require unconventional and expensive laboratory and field tests will find little acceptance in geotechnical engineering practice.

Instrumentation

Geotechnical site response prediction studies in the United States today do not usually incorporate the most advanced soil models. Lack of trust in state-of-the art models for soft soils in the nonlinear range was identified as an important obstacle for the implementation of these models in practice. Model validation through observations from densely instrumented sites capable of detailed measurement of earthquake-induced stresses and strains would be highly desirable. These sites would also permit the study of motion coherency over relatively small distances, which may significantly affect foundation behavior in some cases. In this regard, priority should be given to soft clay deposits with a high probability of being driven into the nonlinear range, with dense instrumentation extending to at least 30 m depth and separated no more than 30 m in plan.

Dense arrays, with instruments at meter-or even sub-meter vertical spacing, would require new MEMS-based instrument designs, such as the Shape-Acceleration-Sensor (SAS) array device [2] or the Terra-Scope package [3]. It should be noted that these instruments are not designed to be recoverable for repair or replacement of individual units so, until their level of survivability in the ground over a period of years is established, they would have to be installed in parallel with more conventional instruments.

A suggested 'dense' array of conventional instruments envisages placing at least three per layer, at top, bottom and center. Layers with strong impedance contrasts at their boundaries should be given priority. With regard to other types of conventional instrumentation, the possibility of replacing accelerometers with three-component long-period low-gain velocity sensors was discussed. The advantages of such strong-motion seismometers over accelerometers would be in reducing errors in signal integration to obtain dynamic displacements (and thus strains) while easily permitting signal derivation to obtain accelerations (and thus stresses). They would also be capable of recording-long period basin effects which cannot be detected by accelerometers of conventional design. It should be noted that seismometers of this type have been installed by the U.S. Geological Survey (USGS) in the Marina District of San Francisco [4] [5] [6].

With regard to the measurement of permanent displacements of the ground, or of structures, by integration of accelerometer or strong-motion seismograph signals, the importance of measuring three components of rotation as well as translation (e.g., Trifunac and Todorovska [7]) was also pointed out; field tests of tri-axial rotation transducers have been made in Taiwan, and more installations are planned [6].

GUIDELINES FOR INSTALLATION AND LONG-TERM OPERATION OF GEOTECHNICAL STRONG-MOTION ARRAYS

Session 2 began with the moderator Robert Nigbor providing an overview of guidance needs for GSMA design, installation, and operation. This presentation included a discussion of needed guidance, with an "Array Lifecycle" concept that was a useful framework for further discussion. Available guidelines relating to GSMA issues were presented, including those from IASPEI and ANSS as well as various recent workshops and conference sessions.

Jamie Steidl then presented two case histories of GSMA installation and operation. He discussed his continuing experience with the Garner Valley Downhole Array (GVDA) and the Wildlife Array (WLA), GSMA's in California that he and his colleagues have operated for two decades. These are now funded by NEES. Lessons learned included the need for multiple funding sources and the need for coordination and collaboration.

Christos Pappaioannou then discussed the ongoing experience with the operation and evolution of the EuroSeisTest facility in Macedonia. In addition to providing a technical overview of the facility, he discussed funding and operational challenges for this decade-old GSMA and seismic test facility.

The extensive collective experience in Taiwan was next presented by George Liu [6]. In addition to the dense strong ground motion network that covers the country, there are many GSMA's in Taiwan. Noteable are SMART-I and II, Lotung, and Hualien arrays. Dr. Liu discussed the role of instrument performance evaluation, a strong feature of the Taiwan experience.

Anthony Shakal updated the workshop participants on developments in the CGS/Caltrans GSMA program. There are now 22 GSMA's operated by this program, with between 6 and 21 accelerometer channels per array. Access to the data and metadata is through the Engineering Strong Motion Data Center on the web. In response to questions, Dr. Shakal discussed the funding status, both for new installations and operation of existing arrays.

The final presentation in this session was by Carl Stepp [8]. He presented strategies for long-term operation of GSMA's, focusing on the funding and on the cooperation and collaboration needed to insure the collection of high-quality array data from infrequent earthquake events.

An active discussion about the need for formal GSMA guidelines and on mechanisms for insuring long-term operation of existing and future arrays followed the presentations. Following are recommendations distilled from these discussions:

- Regarding guidelines, the community should take advantage of existing guidance such as that mentioned in Nigbor's talk. It would be useful to put together a reference document, perhaps in the form of an overview paper in a technical journal or through a COSMOS publication. This document should, in addition to reviewing existing guidelines, assess the need for further formal guidance.
- A strong recommendation was the development of a national (U.S.) panel to oversee and coordinate the operation of the various GSMA's now operating in the United States. Such a panel could assist in the long-term operation by looking at combinations of funding or efficiencies of operation that benefit multiple arrays, could help in the development of new GSMA's, and could provide periodic reviews of the GSMA inventory as an aid to setting support priorities. COSMOS would be a logical institutional home for such a panel.
- International coordination is also critical to maximize the quality and scope of GSMA data. An international extension of the US panel mentioned above might be a future goal, but in the short-term such international coordination should probably remain informal.

DATA ARCHIVING AND DISSEMINATION STRATEGIES

The Session 3 Discussions followed presentations by groups explaining Internet-based data dissemination systems that are or will soon be, available for general Internet access. These are as follows: the COSMOS Strong-Motion Virtual Data Center (SMVDC) [9], the COSMOS Geotechnical Virtual Data Center (GVDC), the DIGGS Standard for International Exchange of Geotechnical Data [10], and the NEESit Data Exchange Model. The presenters gave their reasons for developing their systems and described the method of access and use of the systems. The main motivation for development of the systems is to make data developers' and providers' databases more accessible and available to their own organizations, thereby increasing efficiency for acquisition of additional data and reducing cost. A significant additional motivation was to make data efficiently available to the general user community and realize additional operational and cost benefits by ready sharing of data between organizations. Generally, issues raised during discussions of the presentations centered on standard versus non-standard formats for the data and on the need to find funding in order to continue these projects and to provide for sustained implementation of the systems when fully developed.

In his introduction to the Session 3 discussion, John Bobbitt emphasized that a central requirement for the successful development, implementation, and long-term operation of an internet-based data dissemination system must involve either a cooperative effort by a group of committed users who gain value from the system, or a generally high level of coordination, cooperation, and collaboration among data developers, data providers and data users. He emphasized that the discussion should consider coordination, cooperation, and collaboration to be goals and that the discussion should explore what the geotechnical earthquake engineering community needs to do in the context of these goals in order implement an internet-based data archiving and dissemination infrastructure for geotechnical strong-motion array data.

Three different levels of data sharing and access were defined for discussion.

1. **Internet queryable**. Internet queryable data are organized and made available in a way that can be queried across the Internet. For example, the COSMOS GVDC permits queries on the locations of boreholes.
2. **Internet accessible**. Internet accessible data are not queryable, but can be found and obtained quickly across the Internet. For example (using the COSMOS GVDC again), a user can obtain the results of a moisture content analysis, but cannot query on it. That is, the user cannot find all tests (and holes) with moisture content greater than 20% for example.
3. **Archived**. Archived data are available somewhere. But it normally will require some work to find and obtain them in a useful form. For these data in general, there is not an Internet service that allows the user to locate and download the data very quickly.

These distinctions are important in order to address the question: "What data need to be made available at what sharing and access level?" The answer to this question is driven by usage cases - what will the data be used for? It may be a waste of time and resources to make a set of data Internet accessible if its only use is in a 3-6 month research project. Consequently, how data will be used is an important consideration for determining the appropriate level of sharing and access.

There was general agreement that it is very useful to have a catalog database; a database that keeps basic information about available datasets, but the datasets themselves need to be structured in databases maintained by the data providers. A user would search the data catalog then be transferred to the data provider to download a dataset. One example discussed was the possibility of using DIGGS standard as the standard for reporting and cataloging geotechnical data required to support projects that have regulatory oversight. Such standardization coupled with Internet-based dissemination system provide for ready exchange of data, facilitate efficient regulatory review, and potentially significantly reduce costs.

It is important to develop strategies for management of potential barriers to long-term implementation of an Internet-based data archiving and dissemination system in order to make the right data available at the right level of access? Experience has shown that barriers typically involve people, process, and technology. The technology barriers are the easiest to overcome and these are being addressed by the four projects described Session 3. The process barriers require time and effort, but usually can be resolved. Process barriers also are being addressed by the four projects described in this Session 3. The people barriers are most difficult to overcome and must be given ongoing attention. Consequently, data archiving and dissemination strategies need to provide for structures that ensure strong coordination, cooperation, and collaboration so critical to success.

The developmental projects described in Session 3 are being funded by different sources. The National Science Foundation (NSF) in collaboration with participating data providers USGS and California Geological Survey (CGS), has funded development of the COSMOS SMVDC and USGS and CGS are funding current continuing evolution of the system and its operation. The NSF alone is funding development of the NEESit Data Exchange Model. Consortia constituted of organizations (state's department of transportation) that are data providers and also data users are supporting the development of the DIGGS Standard and the COSMOS GVDC (PEER Lifelines Project). However, strategies and mechanisms for long-term maintenance and upgrade of these systems remain to be developed. There was a strongly expressed view among the users participating in this workshop that data should be available to all users at no cost. The general view is that costs for populating and maintaining the databases should be borne by the data providers and that the cost of implementation and long-term operation of data dissemination systems should be supported by public funds.

The following specific recommendations for developing data archiving and dissemination strategies grew out of the discussion.

- Geotechnical strong-motion array waveform data and associated metadata should be provided to and archived by the US National Center for Engineering Strong Motion Data (NCESMD) ([13]; http://www.quake.ca.gov/ncesmd) and be disseminated by the Center and also through the COSMOS Strong-Motion Virtual Data Center (http://db.cosmos-eq.org).
- Actions needed to link the NCESMD and COSMOS SMVDC with the COSMOS GVDC should be developed and implemented in the near term. A user obtaining strong-motion data from either the NCESMD or the SMVDC would seamlessly search the GVDC for geotechnical data relevant to the strong-motion recording sites of interest.
- A Special Interest Group (SIG) should be established to provide coordination and oversight for implementation and long-term operation of an Internet queryable geotechnical virtual data center. The SIG could be formed under and facilitated by NEESinc for example. It should have representative participation by the appropriate spectrum of stakeholders: geotechnical database providers, geotechnical data user organizations, and private sector companies that develop geotechnical and geoenvironmental software products. The COSMOS GVDC System, which uses the DIGGS data exchange model, provides technical infrastructure for an Internet queryable geotechnical virtual data center that could be adopted for implementation of the system.

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