

## EARTHQUAKE ENGINEERING RESEARCH INSTITUTE

### AD HOC COMMITTEE ON SOIL LIQUEFACTION DURING EARTHQUAKES

W.D. Liam Finn, Steven L. Kramer, Thomas D. O'Rourke (Chair), and T. Leslie Youd

August 16, 2010

**TO:** EERI Board of Directors  
**FROM:** EERI Ad Hoc Committee on Soil Liquefaction During Earthquakes: W.D. Liam Finn, Steven L. Kramer, Thomas D. O'Rourke (Chair), and T. Leslie Youd  
**RE:** Final Report: Technical Issues in Dispute with EERI MNO-12, *Soil Liquefaction During Earthquakes*

During May, 2010 the Ad Hoc Committee on Soil Liquefaction During Earthquakes was formed at the request of the EERI Board of Directors for advice regarding technical and monograph preparation issues associated with EERI Monograph MNO 12: *Soil Liquefaction During Earthquakes*. The purpose of the committee, as developed in consultation with the EERI President and Executive Director, is as follows: "The purpose of the ad hoc committee is to review the technical issues in dispute with EERI MNO-12, *Soil Liquefaction During Earthquakes*, which were raised by Professor Raymond B. Seed of the University of California at Berkeley, and advise the EERI Board of Directors on ways to resolve them. The ad hoc committee will also review and advise the EERI Board on various procedural issues pertaining to the nature of an EERI monograph and monograph review process."

The Committee was unanimous in its decision to not deal with ethical issues raised in conjunction with the monograph.

The Committee's review was based on detailed study of the monograph MNO 12 (Idriss and Boulanger, 2008), the Technical Review and Comments provided by Professor Seed (Seed, 2010), and the extensive experience of the committee members in dealing with liquefaction problems. Preliminary responses to Professor Seed by Professors Izzat M. Idriss and Ross W. Boulanger, the authors of monograph MNO 12, were made available for committee review. The views of each committee member were expressed in an individual presentation to all committee members, and then all comments were discussed at length. Based on this review, the Committee agreed that steps should be taken to resolve the controversy in the interest of advancing professional practice. Review comments and recommendations are provided in this report under the headings that follow.

#### **EERI Monograph**

An EERI Monograph is a report prepared typically by one or two authors, who are invited by EERI to address the state of practice or art in a particular area of earthquake engineering, or provide an introduction to an emerging field of earthquake engineering. The authors are chosen because of their experience and peer recognition as leading experts in the monograph subject area. A monograph is not intended to provide a consensus view of the engineering community, nor is it endorsed in any way as best practice. Each monograph presents the points of view of its author or authors.

It is the opinion of the Committee that monograph MNO 12 was prepared in a manner consistent with the general description and goals, including limitations, of a monograph as

stated above. Monograph MNO 12 represents a systematic and detailed treatment of liquefaction by reputable experts, who were invited in the tradition of monograph preparation to express their views about the monograph subject. The procedures followed in preparing and providing oversight for the monograph, including external, expert review, were consistent with those followed in the preparation of previous EERI monographs.

The resulting monograph represents an important contribution to the engineering profession. Professors Idriss and Boulanger are to be commended for their dedicated service, careful work, and commitment to a high standard of scholarship in producing the document. The monograph, however, is an exposition of their studied opinions and views on liquefaction, which is reinforced by the disclaimer on the back of the title page, in which "any opinions, findings, conclusions, or recommendations expressed herein are the authors' and do not necessarily reflect the views of FEMA or EERI."

The Committee recognizes that an EERI monograph carries special prestige and provides a highly visible and potentially influential contribution to engineering practice by virtue of its accessibility through the Institute and the publicity accorded to it by EERI. The publication of monograph MNO 12 was accompanied by a series of technical seminars sponsored by EERI in a number of US and Canadian cities. The number and scale of promotion of the seminars were a departure from previous practice. Some Committee members have spoken with seminar attendees, who were under the impression that the combined monograph publication and technical seminar series represents an EERI endorsement of monograph contents. Whereas the technical seminars have offered a very valuable professional service, they have apparently left some attendees with the impression of a *de facto* endorsement of monograph content, even though this type of support is at variance with the disclaimer.

## **History**

EERI published a monograph (MNO-5) titled "Ground Motions and Soil Liquefaction During Earthquakes" (Seed and Idriss, 1982), which presented the approaches to liquefaction hazard evaluation that had been developed by its authors. A National Research Council (NRC) workshop chaired by R.V. Whitman resulted in a comprehensive report on the subject (NRC, 1985). In 1996 and 1998, participants in NSF/NCEER workshops chaired by T.L. Youd and I.M. Idriss reached consensus on a number of liquefaction issues, which they described in an influential report (Youd and Idriss, 1997) and paper (Youd et al., 2001). Those workshops represent the most recent point at which a general consensus on liquefaction procedures existed. Since that time, several major earthquakes have occurred and been investigated, resulting in a substantial amount of new data on liquefaction behavior.

Over the past 10-12 years, a number of research groups have studied liquefaction phenomena in great detail. Idriss and Boulanger published a series of papers in refereed journals and major conference proceedings. The contents of MNO-12 are largely based on those papers and, as indicated in MNO-12, present procedures that extend, but are generally consistent with, the consensus procedures resulting from the 1996 workshop. R.B. Seed and colleagues presented the results of their own research in a comprehensive paper (Seed, et al., 2003), and refereed journal publications on standard penetration test (SPT)- and cone penetration test

(CPT)-based liquefaction triggering procedures were subsequently published (Cetin, et al., 2004, Moss, et al., 2006).

### **Differing Points of View**

Much progress has been made in understanding the liquefaction phenomenon and in developing procedures for predicting its occurrence and mitigating deleterious effects. However, due to the complexity of the phenomenon, usual engineering procedures, including analytical modeling and laboratory testing, have not matured to the point where they can be applied with confidence. The present state of the art for engineering design and construction relies heavily upon empirical procedures, which are based primarily on interpretations of collected case histories and past performance of constructed works.

As a consequence, there are alternate, viable views and studied opinions about liquefaction, some of which have been presented by Professor Seed. These alternative viewpoints are important in that they represent the breadth of effects associated with different interpretations of available data. However, they can raise significant concern among practitioners when they lead to substantially different results.

In some instances there are substantial differences among the procedures proposed by Seed and his colleagues and Idriss and Boulanger relative to those contained in the NSF/MCEER workshop publications (Youd and Idriss, 1997, Youd et al., 2001), which represent the most recent consensus documents on liquefaction. These differences can be significant, especially when evaluating liquefaction for dams, where the depths to the liquefied zones may be considerable. Idriss and Boulanger on page 103 of monograph MNO 12 show that, at a depth of 20m and corrected blow counts  $(N_1)_{60} < 35$ , their method can produce factors of safety against the triggering of liquefaction that are about 80%-110% of the safety factors obtained with the NSF/NCEER workshop methods. In contrast, the procedures proposed by Seed and coworkers for the same conditions produce factors of safety that are approximately 60-90% of those derived from NSF/NCEER workshop methods. The differences among the procedures may be even larger at greater depths.

These differences can have important implications for public safety and the costs of large civil infrastructure projects, involving potentially hundreds of millions of dollars.

The Committee has identified some technical issues that, in its opinion, deserve further review and resolution by the geotechnical earthquake engineering community. These technical issues are cited in this report as examples, and are neither ranked nor intended to represent all important issues. The issues may be classified into three categories; triggering of liquefaction, consequences, and modeling. Triggering includes such issues as definition of liquefaction; role of plasticity and water content; role of depth-dependent variables, such as  $r_d$ ,  $K_o$ , etc.; mutual consistency of SPT- and CPT-based procedures; and dense soil behavior. The consequences are affected by post liquefaction soil strength, lateral spreading, and settlement. Modeling issues include data vetting; documentation and transparency; use of laboratory data and theoretical constructs; and extrapolation, probabilistic, and deterministic treatments of data.

It must be emphasized that this listing of issues is not exhaustive, but is provided in the hope that it will encourage additional discussion leading to community-wide resolution of the issues. To this end it is critically important to provide a forum in which alternative views on liquefaction can be expressed, evaluated, and debated objectively; consensus opinions formulated where possible; and differing procedures compared and clearly presented.

Successful workshops that accomplished these objectives were held in 1985 [organized by the National Research Council (NRC 1985)] and in 1996 and 1998 under sponsorship of NCEER and NSF (Youd and Idriss 1997, Youd et al 2001). The 1996 workshop led to development of consensus procedures for evaluating liquefaction resistance. The 1998 continuation of the 1996 workshop considered additional issues and resolved a few disagreements that developed with respect to recommendations from the 1996 workshop. The results of the two workshops were summarized in a widely used journal paper, readily accessible to most practitioners (Youd, et al., 2001). The workshops contributed substantially to the development process, produced written reports endorsed by the assembled experts, and greatly benefited users, who could then apply the consensus procedures or select from differing approaches with a clearer understanding of their advantages and limitations.

### **The Way Forward**

One of the best paths forward is to expand the current debate about the technical issues in monograph MNO 12 to a broader discussion and resolution of liquefaction issues affecting the entire geotechnical earthquake engineering community. A process is needed for expanding the current, sometimes personalized debate about liquefaction into a community-wide examination of the state of the art.

EERI can help facilitate the process of developing a community-wide evaluation of liquefaction and its engineering consequences by promoting a third major liquefaction workshop to consider the current state of knowledge and practice in liquefaction hazard evaluation, including significant technical differences, new or enhanced developments that have occurred since the last workshop, and future directions in this area. The workshop should include a report that summarizes the geotechnical earthquake engineering community's views on the appropriate engineering practices for evaluating the potential for liquefaction and its consequences.

Given the potentially large differences in the results of the alternate liquefaction assessment procedures and their potential impact on the safety and cost of important civil infrastructure projects, there is considerable urgency to resolve differing points of view. The Committee acknowledges this urgency, and strongly encourages EERI to promote corrective actions through a workshop at the earliest possible date.

Because of the significance of current technical differences and the need for high-level involvement by experts in the profession to resolve the controversies, the Committee recommends that this workshop be organized through the auspices of the National Academies of Engineering and Science and their operational arm, the National Research

Council. There is ample precedent for successful workshops on liquefaction, and an appropriate blueprint for a forthcoming workshop can be obtained from experience gained with the previous two. Organization of the workshop through the National Academies is advantageous because it establishes high, objective standards for workshop participants, carries substantial professional prestige, and provides for a fair and balanced external review.

The Committee considered alternate professional societies and earthquake engineering centers as lead institutions, but believes that management through the National Academies removes concerns about potential institutional biases and local affiliations. Because of the public safety and economic importance associated with the disputed liquefaction issues, there is ample justification for workshop support from NEHRP agencies, such as NIST, NSF, and FEMA, as well as other federal and state agencies.

When developing the workshop, the Committee believes that it is important to promote a constructive and cooperative basis for community interaction. Given the intensity of personal feelings stimulated by the current debate and the need for a balanced and fair treatment of differing points of view, great care needs to be exercised in choosing the members of the workshop organizing committee. The members of the organizing committee should be carefully screened to promote productive and constructive interaction, and avoid conflicts of interest.

Because the lead time for a workshop sponsored by the National Academies may be long, an interim approach may be advantageous in which Professor Seed and coworkers are invited to prepare and publish one or two papers in *Earthquake Spectra* subject to the journal external review process. The opportunity to present new findings in *Earthquake Spectra* would also be extended to Professors Idriss and Boulanger. The reviews would be expedited and handled anonymously by expert reviewers not closely associated with Professors Seed, Idriss, or Boulanger. The prospective authors would be asked to prepare papers that focus on the advantages and limitations of the procedures they developed. Although some comparison with alternative procedures will be required, such comparisons should use the type of neutral and professional language expected in a high-quality refereed journal.

It is recommended that the papers be open to discussion from all interested members of the earthquake engineering community and that such discussions be published in a subsequent issue of *Earthquake Spectra*, with an opportunity for closure by the authors. It is recognized that discussions of technical papers are not normally part of the *Earthquake Spectra* publication process. Nonetheless, the Committee believes that discussions in this instance are highly advisable. A published paper and subsequent discussions provide the opportunity for airing differing points of view, encouraging fair and open debate on the issues, and may help to ease some of the tensions that have been generated by proponents of alternate approaches, thus helping the transition to a community-wide discussion and workshop that examines the state of the art. Procedures for discussions of published papers are well established in journals such as the *ASCE Journal of Geotechnical and Geoenvironmental Engineering*.

Although the Committee encourages publication in *Earthquake Spectra*, the ASCE journal may provide an alternative forum for the invited papers. EERI through its memorandum of

understanding with the ASCE GeoInstitute may be able to organize and expedite publication in the *Journal of Geotechnical and Geoenvironmental Engineering*, which automatically entails publication of discussions in a subsequent issue. The Committee recognizes that ASCE journal publication entails coordination and agreement with a separate organization as well as agreement from the prospective authors, and that there may be practical constraints in pursuing this option.

### **Future EERI Monographs**

As discussed previously, the preparation and oversight procedures for monograph MNO 12 were consistent with those followed for previous EERI monographs. Normally, there have been three to four external reviewers of recent monographs, whereas there were eight for MNO 12. Thus, if there was a difference in process, it entailed a larger than typical number of reviewers. However, the present controversy suggests that a more formal review process is necessary in which EERI has control over the selection of referees and the handling of review comments.

In the case of MNO 12 the reviewers were known to the authors, and in most instances were asked directly by the authors to provide comments. The reviews were thus offered in a friendly manner and were focused on clarifications and improving the exposition of content, rather than challenging content on the basis of differing points of view. Moreover, explicit responses to the reviewers' comments appear not to have been provided.

If future monographs contain procedures with potentially large effects on public safety and project costs, it is advisable to provide anonymous reviews, consistent with the review process followed by leading, refereed journals. This approach would include appointment of all reviewers by EERI directly, with the reviews sent to and processed by EERI, and then sent to the authors, who would provide a formal, written response to the reviewers' comments.

This approach is especially helpful if procedures in the monograph are presented on a first time basis, are not widely accepted, or controversial. Such a review process often provides a more rigorous and critical review, with either change or written justification by the author or authors for monograph content questioned by the reviewers. Thus, there are additional safeguards that identify potential problems, test the basis for recommended procedures, and strengthen the document for use by practitioners.

### **Summary of Recommendations**

The Committee recommends that EERI broaden the discussion and resolution of liquefaction issues raised in conjunction with monograph MNO 12 by promoting a major liquefaction workshop conducted under the auspices of the National Academies to consider the current state of knowledge and practice in liquefaction hazard evaluation. The Committee further recommends that steps be taken to facilitate a workshop at the earliest possible date. Justification for and characteristics of the workshop are discussed in this report. The goal is for EERI to transfer the current debate to a community-based evaluation of the state-of-the-

art of liquefaction assessment. EERI is in an excellent position to facilitate this transfer and, in the process, demonstrate its responsiveness to promoting a community-wide resolution of differing points of view.

The Committee also recommends that EERI invite Professor Seed and coworkers to publish one or two papers in *Earthquake Spectra* subject to the journal review process. The opportunity to present new findings in *Earthquake Spectra* would also be extended to Professors Idriss and Boulanger. The review would be expedited and handled anonymously by expert reviewers not closely associated with Professors Seed, Idriss, or Boulanger, according to the general guidance provided in this report. The papers should be open to discussions from all interested members of the earthquake engineering community, and would be published in a subsequent issue of *Earthquake Spectra*, with an opportunity for closure by the authors.

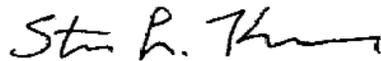
The Committee recommends a review of monograph editorial policy guided, but not controlled by the issues raised in relation to the liquefaction monograph. When future monographs have the potential to affect substantially public safety and project costs, it is advisable to provide anonymous reviews to promote a critical, rigorous assessment of technical issues. Authors should supply written justification, if review comments are not implemented.

Respectfully submitted,



---

W.D. Liam Finn



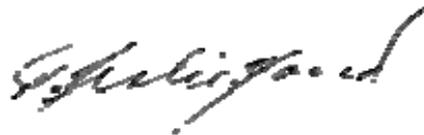
---

Steven L. Kramer



---

Thomas D. O'Rourke (Chair)



---

T. Leslie Youd

**References:**

Cetin, K.O., Seed, R.B., Der Kiureghian, A., Tokimatsu, K., Harder, L.F., Kayen, R.E., and Moss, R.E.S., 2004, "Standard penetration test-based probabilistic and deterministic assessment of seismic soil liquefaction potential," ASCE, Journal of Geotechnical and Geoenvironmental Engineering, v. 130, No. 12, pp. 1314-1340.

Idriss, I.M. and Boulanger, R.W., 2008, *Soil liquefaction during earthquakes*, EERI MNO-12, 235 p.

Moss, R.E.S., Seed, R.B., Kayen, R.E., Stewart, J.P., Der Kiureghian, A., Cetin, K.O., 2006, "CPT-based probabilistic and deterministic assessment of in situ seismic soil liquefaction potential," ASCE, Journal of Geotechnical and Geoenvironmental Engineering, v. 132, No. 8, pp. 1032-1061.

National Research Council (NRC), 1985, *Liquefaction of soils during earthquakes*, Washington, D.C., Committee on Earthquake Engineering, National Research Council, 240 pp.

Seed, H.B. and I.M. Idriss, 1982, *Ground motions and soil liquefaction during earthquakes*, EERI Monograph MNO-5, 134 p.

Seed, R.B., Cetin, K.O., Moss, R.E.S., Kammerer, A.M., Wu, J., Pestana, J.M., Riemer, M.F., Sancio, R.B., Bray, J.D., Kayen, R.E., and Faris, A., 2003, "Recent advances in soil liquefaction engineering: a unified and consistent framework," unpublished report, ASCE Los Angeles Geotechnical Spring Seminar, Keynote Presentation, Long Beach, CA, 71 p.

Seed, R.B., 2010, *Technical review comments: 2008 EERI monograph "Soil liquefaction during earthquakes (by I.M. Idriss and R.W. Boulanger)"*, University of California at Berkeley Geotechnical Report No. UCB/GT-2010-1, 75 p.

Youd, T.L., and Idriss, I.M., eds, 1997, NCEER workshop on evaluation of liquefaction resistance of soils, National Center for Earthquake Engineering Research Technical Report NCEER-97-0022, pp. 276 p.

Youd, T.L., Idriss, I.M. Andrus, R.D. Arango, I., Castro, G., Christian, J.T., Dobry, R., Liam Finn, W.D.L., Harder, L.F., Jr., Hynes, M.E., Ishihara, K., Koester, J.P., Liao, S.S.C., Marcuson, W.F., III, Martin, G.R., Mitchell, J.K., Moriwaki, Y., Power, M.S., Robertson, P.K., Seed, R.B., Stokoe, K.H., II, 2001, Liquefaction resistance of soils: summary report from the 1996 NCEER and 1998 NCEER/NSF workshops on evaluation of liquefaction resistance of soils, ASCE, Journal of Geotechnical and Geoenvironmental Engineering, v. 127, no. 10, pp. 817-833.