2013 ULAG MEETING SUMMARY
Utah Liquefaction Advisory Group
Monday, February 4, 2013
Utah Department of Natural Resources Building, Room 1050

Steve Bartlett, U of U, Chair
Mike Hylland, UGS, Coordinator

Members present:
Steve Bartlett, U of U
Ryan Cole, Gerhart Cole, Inc.
Kevin Franke, BYU
Grant Gummow, UDOT
Jim Higbee, UDOT
Mike Hylland, UGS
David Simon, Simon Bymaster, Inc.
Bill Turner, GHS Geotech Consultants
Les Youd, BYU

Invited guests:
Dan Gillins, OSU
Gary Norris, UNR

INTRODUCTION

Overview of ULAG Objectives, Summary of Recently Completed Work, and Work in Progress

The meeting commenced at 8:30 a.m. with 40 attendees. After brief introductory remarks by Mike Hylland, Steve Bartlett summarized the objectives of the Utah Liquefaction Advisory Group (ULAG), recently completed work, and work in progress.

ULAG objectives:

1. Development of probabilistic liquefaction hazard maps (including liquefaction triggering, lateral spread, and seismically induced ground settlement) for the urban Wasatch Front counties.
2. Development of GIS programs for implementing the probabilistic hazard maps.
3. Establishment of a subsurface geotechnical database for public use.
4. Education and public outreach.

Recently completed work:

- Probabilistic liquefaction hazard maps for Weber County, 500- and 2500-yr return periods (Dan Gillins, University of Utah [U of U] Ph.D. dissertation).

Work in progress:

- New U of U–Utah Geological Survey (UGS) project funded by the Federal Emergency Management Agency Hazard Mitigation Grant Program and administered by the Utah Department of Public Safety, Division of Emergency Management: "Implemetation of Risk-based Liquefaction Maps in Hazard Ordinances and Risk-based Decision Making."

- Project objectives:
  1. Develop a new model ordinance for liquefaction hazards based on input and feedback from municipalities, technical advisory groups, and others.
  2. Educate various municipalities and their stake holders regarding risk-based decision making and hazard mitigation using the newly developed hazard ordinance that is coupled with the recently developed ULAG liquefaction hazard maps and support and encourage the implementation/adoption of the new liquefaction hazard ordinance in the various municipalities along the urban Wasatch Front.
  3. Develop methods to apply the liquefaction hazard maps to assess post-event traffic interruptions resulting from liquefaction-induced damage
  4. Educate the next generation of Utahns about earthquake hazards by focusing on a secondary education outreach curriculum and program delivered to Salt Lake and Weber Counties.

Note that past ULAG meeting agendas, meeting summaries, and presentation files may be found on the UGS ULAG web page (http://geology.utah.gov/ghp/workgroups/ulag.htm), and products resulting from ULAG-related research may be found on the U of U ULAG web page (http://www.civil.utah.edu/~bartlett/ULAG/).

TECHNICAL PRESENTATIONS

Mapping the Probability of Liquefaction-induced Ground Failure

Dan Gillins, Oregon State University

Dan summarized the liquefaction hazard mapping project he did for his University of Utah Ph.D. dissertation. His mapping in Weber County, Utah (liquefaction-triggering and lateral-spread hazard maps), focused on the development of an approach for characterizing under-sampled surficial geologic units. The basic model being used to determine lateral spread displacements is the multiple linear regression model of Youd and others (2002). Available borehole data for Weber County include little to no information on fines content and mean grain size (F_{15} and $D50_{15}$ terms, respectively, in the Youd and others model). In Dan's new empirical model, a Soil Index (SI) parameter based on soil type (derived from soil descriptions in borehole logs) is substituted for fines-content and mean-grain-size terms. The SI parameter also allows correlation with cone penetrometer data. Dan produced earthquake-induced liquefaction hazard maps showing probabilities of liquefaction triggering and lateral ground displacements at 500- and 2500-yr return periods. A major contribution of the mapping effort is the development of a method for estimating the uncertainty in the ground-displacement predictions. Dan's dissertation can be accessed at http://www.civil.utah.edu/~bartlett/ULAG/Gillins_dissertation.pdf.

Got Risk? Some Advantages of Performance-based Design in Evaluating Liquefaction and its Effects

Kevin Franke, Brigham Young University

Kevin presented a comparison of performance-based liquefaction assessment with traditional liquefaction analysis, focusing on the performance-based design (PBD) model of Kramer and Mayfield (2007). Advantages to the PBD approach include treatment of uncertainty, evaluation of liquefaction and its effects in terms of probability and uniform hazard, consistency across different seismic environments, less subjective decisions, and compatibility of results with higher order risk-based analyses. However, the PBD approach is difficult to perform, and a simplified procedure exists (Mayfield and others, 2010) that can be used to develop liquefaction parameter maps, which yield probabilistic liquefaction triggering profiles when combined with site-specific soil borehole data. Kevin showed a good correlation of results where the full and simplified PBD procedures were compared at 10 U.S. cities in different seismic settings.

BYU-IEM Collaborative Research

Les Youd, Brigham Young University

Les summarized an ongoing collaborative liquefaction research effort between Brigham Young University (BYU) and the Institute of Engineering Mechanics (IEM), People's Republic of China. The collaborative studies came about partly as the consequence of research by Zhenzhong Cao (visiting scholar at BYU), conducted after the 2008 M_s 8.0 Wenchuan earthquake and involving dynamic penetration testing (DPT) of liquefied gravels. A paper has been accepted for publication in the Journal of Geotechnical and Geoenvironmental Engineering, describing the DPT and highlighting the potential application of DPT in the U.S. and other countries. Ongoing BYU-IEM research (through 2016) will work toward improved techniques for prediction and mitigation of liquefaction hazard, with a focus on liquefaction assessment methods for gravelly soils and sensor/instrumentation needs in geotechnical earthquake engineering.

Recovery of Liquefied Sand with Increasing Undrained Shear Strain

Keynote presentation by Gary Norris, University of Nevada, Reno

Gary summarized research that he has conducted, together with Mohamed Ashour, Tung Nguyen, Horng-Jyh Yang, and Sherif Elfass, to develop a method for assessing the stress-strain and effective stress path response of a sand recovering from complete liquefaction. The abstract for his presentation follows:

> The recovery in stiffness and strength of liquefied sand with increasing and large undrained shear strain has been recognized for some time. However, the behavior has not been explained heretofore, but has been a black-box mystery. This presentation will provide a simple evaluation of this phenomenon based on isotropically consolidated, rebounded, drained triaxial test stress-strain and volume change behavior. Such drained triaxial test response has been successfully used to evaluate static undrained triaxial test stress-strain and effective stress path response. The formulation is employed in the laterally loaded pile/shaft p-y curve response program DFSAP, to evaluate pile/shaft and group response in liquefiable sand under inertial loading from seismic excitation. The modified Hooke's Law effective stress basis of analysis will also be discussed. This

includes the development of the stress-strain curves and effective stress path based on regularly obtained geotechnical input and easily applied equations.

Note that DFSAP (Deep Foundation System Analysis Program) is available for free download through the Washington State Department of Transportation website (http://www.wsdot.wa.gov/eesc/bridge/software/). DFSAP provides direct assessment of the three-dimensional/rotational spring stiffness of an isolated short, intermediate, or long pile/shaft or similar stiffness of a pile/shaft group with or without a cap.

DISCUSSION

A Look Inside the Debate Over EERI Monograph 12

Les Youd led a discussion of the controversy that resulted from Ray Seed's criticism of Earthquake Engineering Research Institute (EERI) Monograph 12, which sets out the procedure by I.M. Idriss and R.W. Boulanger for evaluating liquefaction hazard. Presently, confusion and uncertainty exist within the practicing engineering community as to what empirical procedure best represents the state-of-the-art for liquefaction hazard assessment. After Les introduced the topic with a presentation that he had previously given as a keynote lecture at the California Geotechnical Engineers Association annual meeting in 2011, the discussion was opened up to the working group members and guests. Some of the discussion topics that came up, which represent the ongoing debate, are as follows:

- Su/P□ ratio residual shear strength normalization. Should this be done, or is it better not to do this normalization?
- Equivalent clean sand blow count correction. The clean sand correction for liquefaction triggering is different from the clean sand correction used in estimating the residual strength.
- Static vs. dynamic forces. For most lateral spreads, the static forces existing on the slope are insufficient to cause damaging movements. Generally, the dynamic inertial forces have to be present also.
- Applicability of Newmark analysis to lateral spread.
- Constant residual strengths vs. residual strength ratio—depth dependent?
- Models and problems with databases (data points).
- Void redistribution.

ADDITIONAL PRESENTATION

Utah Geological Survey GeoData Archive System

Steve Bowman, Utah Geological Survey

Steve gave an overview of the UGS GeoData Archive System, a web-based resource for geologic-hazard and geotechnical data and reports in Utah. The GeoData Archive System contains Utah geologic-related scanned documents, photographs (except aerial), and other digital materials from UGS files and those gathered from other agencies or organizations. Resources available to general users are all in the public domain and may contain reports submitted to state and local governments as part of permit reviews. Metadata describing each resource is searchable, along with spatial searching for resources that are local or site-specific in nature. The working group discussed opportunities to expand the GeoData Archive System holdings, including possible assistance from the University of Utah, and perhaps partnering with the Utah Department of Transportation (UDOT; the topic will be brought up with UDOT at a planning meeting this spring). The GeoData Archive System can be accessed at https://geodata.geology.utah.gov.

PLANNING AND PRIORITIES FOR FY2014

General

The working group identified three priority areas for FY2014: (1) liquefaction hazard mapping in Utah County, (2) improved tools for site-specific liquefaction hazard evaluation, and (3) publication of Bart Leeflang's thesis.

(1) Utah County liquefaction hazard mapping—The working group agreed that Utah County is the highest priority area in Utah for new liquefaction hazard mapping. The group identified David Graves and Travis Gerber as individual contacts that may be able to facilitate data collection; UDOT, Utah Transit Authority, and the Central Utah Water Conservancy District as agencies that may be interested in providing support; and cities such as Lehi and Saratoga Springs as expanding municipalities that would benefit from new mapping and may be interested in providing support. Oregon State University was also identified as a possible collaborator, as Dan Gillins has the computer code that was used in Weber County for mapping and uncertainty analyses.

(2) Improved tools for site-specific liquefaction hazard evaluation—In particular, the group agreed that the multiple linear regression (MLR) equations for evaluating horizontal displacements are in need of revision based on an updated dataset. The group recommended pursuing assistance from the Transportation Research Board, as well as the

Washington and Alaska Departments of Transportation (current leaders in seismic bridge design).

(3) Publication of Bart Leeflang's thesis—Bart's University of Utah M.S. thesis, completed in 2008, involved a CPT investigation of the southern projection of the Warm Springs fault in downtown Salt Lake City. The group supports publication of the thesis in a journal such as the Association of Environmental and Engineering Geologists *Environmental and Engineering Geoscience*. Bart's thesis can be accessed at http://www.civil.utah.edu/~bartlett/ULAG/Leeflang_thesis.pdf.

Priorities for NEHRP-funded Research

Liquefaction-related research priorities for 2014, as established by the Utah Liquefaction Advisory Group, include two components:

(1) Application of the revised MLR equations by Gillins (2012) in probabilistic mapping of liquefaction-induced ground failure in Utah County, Utah, a Wasatch Front region of high population growth and extensive infrastructure vulnerable to significant damage from earthquake-induced liquefaction.

(2) Revision/refinement of the existing MLR equations by Youd and others (2002) for determining horizontal ground displacement generated by liquefaction-induced lateral spread, using newer methods and increasing the case history dataset.

The meeting was adjourned at 4:15 p.m. ULAG members and guests were encouraged to attend Gary Norris' evening presentation at the University of Utah; the abstract for his presentation follows:

Analysis of Laterally and Axially Loaded Groups of Shafts or Piles

M. Ashour, G. Norris, and J.P. Singh

This presentation demonstrates the application of the Strain Wedge (SW) model to assess the response of laterally loaded isolated long piles, drilled shafts, and pile groups in layered soil (sand and/or clay) and rock deposits, to illustrate the capabilities of the SW model versus other procedures and approaches. The SW model has been validated and verified through several comparison studies with model- and full-scale lateral load tests. Several factors and features related to the problem of a laterally loaded isolated pile and pile group are covered by the SW model. For example, the nonlinear behavior of both soil and pile material, the soil-pile interaction (i.e., the assessment of the p-y curves rather than the adoption of empirical ones), the potential of soil to liquefy, the interference among neighboring piles in a pile group, and the pile cap contribution are considered in SW model analysis. The SW model analyzes the response of laterally loaded piles based on pile properties (pile stiffness, cross-sectional shape, pile-head conditions, etc.) as well

as soil properties. The SW model has the capability of assessing the response of a laterally loaded pile group in layered soil based on more realistic assumptions of pile interference as compared to techniques and procedures currently employed or proposed.