USSD Static Liquefaction Workshop Agenda

July 09 – 10, 2019

AECOM Building - 6200 S. Quebec St., Greenwood Village, CO 80111

DAY 1

7:15 **Registration opens**

8:30 **Welcome and introduction**

8:45 **Soil mechanics review**

- Essential fundamental soil mechanics concepts are reviewed, including principal stresses, plane strain idealization, Mohr's circle of stress, effective stresses and shear strength. Three distinct mechanisms of excess pore pressure are discussed, emphasizing the often-overlooked mechanism of shear induced pore pressure changes. This section finishes off with an introduction to the concept of Critical State, dilatant and contractive behavior.

9:45 **Cone penetration test 1 – overview**

- This section serves as an overview to cone penetration testing, including the equipment typically used, conventional theory for CPT data interpretation, the importance of dissipation tests and interpretation of resulting data and differences between undrained and drained penetration rates. A brief introduction to the use of seismic cones is also provided.

10:45 **Morning break**

11:00 **Static liquefaction**

- The concept of static liquefaction will be defined based on commonly accepted terms found in modern literature. It will then be illustrated through examples from laboratory tests and failure case histories. The instability stress ratio (or instability locus) will be discussed along with how it related to undrained shear strength. The common trigger mechanisms leading to static liquefaction will be discussed in both a theoretical and practical context. Questions will be presented as to what types of behavior or soils types would be considered the "bounds" of static liquefaction, compared to more general contractive undrained shearing.

12:30 **Lunch**

13:30 **Case histories**

- Major case histories that included static liquefaction, either as primary cause or as an exacerbating event will be outlined in detail. These will include Merriespruit, Fundão, and Cadia. The investigations at each deposit after failure will be linked to the concepts to be covered in the course. Video evidence of the behavior from multiple sites will be presented, along with a controlled beam centrifuge test to further emphasize the common triggers.

15:30 **Afternoon break**

15:45 **Laboratory testing 1 – overview**

- The types of laboratory test devices available to assess static liquefaction susceptibility will be reviewed, particularly the triaxial and simple shear test. Interpretation of triaxial test data are discussed, and the importance of stress path parameters demonstrated. A brief review of the relevance of principal stress rotation is provided, followed by a discussion of how to prepare and test reconstituted laboratory samples that are adequately representative of in-situ conditions.

16:45 **Questions and discussion**

- A brief review of the day's proceedings will occur, followed by a period for questions and discussions.

17:30 **Day one close**

DAY 2

8:00 **Stability analysis considerations**

- The limitations of the limit equilibrium technique in assessing static liquefaction triggering in brittle deposits, or under some drained stress paths, will be discussed. Limit equilibrium models will be compared to FLAC models of the same geometry, to illustrate issues related to stress localization and brittle stress redistribution. FLAC model codes and limit equilibrium models for these examples will be provided to course attendees. Methods of various complexity used historically to account for brittle stress redistribution will be discussed. Finally, the ongoing debate about when to simply assume post-liquefaction strengths, regardless of triggering potential, will be touched on.

9:30 **Laboratory testing 2 – critical state testing**

- The current state of practice methods for measuring the critical state line (CSL) in the laboratory will be outlined, along with brief historical development and the rationale for the current procedures being used. Sufficient photographs and schematics will be provided to assist laboratories looking to implement this testing protocol. Examples from the literature where the CSL has been measured and used will be outlined, including from recent failure investigations.

10:00 **Morning break**

10:15 **Cone penetration test 2 – inferring state**

- The use of the CPTu to infer in situ state will be covered. Particular focus will be on the historical development of current techniques, and the theoretical basis for estimating state in a inverse boundary problem. Empirical correlations used to provide "screening level" assessments will first be outlined, followed by methods to refine state estimates as additional laboratory data becomes available. A review of the state parameter estimates for the Fundao TSF, and how they relate to the triggering of static liquefaction, will be discussed in detail.

11:30 **Lunch**

12:15 **Static liquefaction in national guidelines**

- The discussion of and guidelines related to static liquefaction as they appear in national guidelines related to TSFs will be reviewed. Particular focus will be on the Australian (ANCOLD) and Canadian (CDA) guidelines for tailings. The FoS related to different components of a stability analysis for a liquefiable deposit will be outlined, along with the limitations of current methods given the known types of drained trigger mechanisms along with brittle stress redistribution (referring to previous sessions).

13:00 **Methods to demonstrate static liquefaction triggering**

- A review of the history of laboratory methods to "prove" the potential for drained loading to trigger static liquefaction will first be carried out, then interspersed with videos of such failures using dead weights for shear stress application. The sudden, dramatic failures seen in these laboratory demonstrations will then be compared to evidence from centrifuge and field-scale static liquefaction events.

13:45 **Afternoon break**

14:00 **Post-liquefaction strength**

- Post-liquefaction (i.e. "residual undrained") strength will be defined in review, and methods to obtain this value from deposits comprising primarily silt and sands will be outlined. A simplified process wherein post-liquefaction strength correlations are developed from field-scale flow liquefaction events will be made. The inherent uncertainties, and their implications to design, will be reviewed. The applicability of these methods to fine-grained

deposits with significant plasticity will be discussed, along with information on the range of procedures available for such materials. Difficulties in measuring post-liquefaction strength in the laboratory will be outlined, including anisotropy and the strain limitations of test devices.

15:00 **Summary and discussion**

- A summary of the course will be made, to provide review and context to enable further discussion with attendees about the topics covered and areas for future study and improvement in techniques.

15:45 **Workshop closure**