SECOND US-JAPAN WORKSHOP ON LIQUEFACTION, LARGE GROUND DEFORMATIONS AND THEIR EFFECTS ON LIFELINES

# REPORT FROM WORKING GROUP NO. 2: MODELING LARGE GROUND DEFORMATION


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## INTRODUCTION

During the workshop, Working Group 2 met to review current progress and to define future directions and needs related to modeling of large ground deformations. The goal of this working group is to develop accepted site-specific analytical techniques to predict the value and spatial pattern of ground deformations for a given earthquake shaking. The decision was made that the modeling should concentrate on the effects of shaking in the absence of structures, i.e. the far field. Five key topical areas that will be addressed in the Guidelines were identified and discussed.

The first important topical area relevant to the development of sound analytical modeling must necessarily include a definition of the physical mechanisms responsible for permanent ground deformations. The mechanisms are mostly associated with gravity, although other contributing factors could be present. Mechanistic effects that play important roles include, but may not be limited to, gravity and seismic stresses per Newmark-type analyses, the effects of delayed deformations, the roles of subsurface flow and the redistribution of pore water pressures, and true inertial forces. The Guidelines will address the above mechanisms, with emphasis on the physics of liquefaction-induced ground deformations.

A second topical area relevant to accurate analytical modeling relates to specific site and earthquake parameters. These parameters must be measurable or at least realistically determined. Four groupings of site parameters were identified. The first group relates to earthquake shaking. The earthquake shaking must be quantified as to the level, frequency content and duration. The shape of the time record is an important factor as well, since unequal cyclic intensities affect the ground response. The second grouping of site parameters revolve around the specifics of surface and subsurface topography and slope, the thickness and depth of liquefiable layers, and the presence of other layered features. Although these parameters can be quantified readily, the importance of subtle differences and features must be addressed. The third grouping of site and earthquake parameters relates to the other site properties not specifically addressed in the second grouping. These include the groundwater conditions, including both the location of the free surface and any subsurface flow conditions. Geologic features such as age, seismic history, cementation, stress history and initial stresses, and the effects of human activities are known to influence site response, but have not been fully quantified. The relative importance of all these factors needs to be understood so that site-specific differences in ground movement can be explained. The fourth grouping of site specific parameters consists of fundamental soil properties. In addition to simple descriptors such as grain size and unit weights, we must be able to account for the nonlinear cyclic stress-strain-strength properties, especially when dealing with large strains. Important properties necessary for accurate modeling also include hydraulic conductivity, compressibility, in-situ lateral stresses, and how these properties change during cyclic loading.

The third topical area identified during the Working Group session that will be included in the Guidelines is devoted to the general analytical methods that are available. Analytical methods for large ground deformation can be classified broadly into three groups: 1) two-phase effective stress, 2) total stress with reduced stiffness, and 3) displacement pattern or geometric methods. Within these broad categories there are several features that should be included in a comprehensive approach. These features relate to effects that can occur during the earthquake, such as sliding, and those that can occur following the motion. During the earthquake, effective stress methods may be more suitable, whereas effective stress based methods, equivalent elastic methods with reduced stiffness, or a continuity-mass balance approach may be used when looking at post-earthquake deformations. The Guidelines will address the requirements necessary for an ideal or high-quality analytical technique. The Guidelines should include a description of what methods are available currently, the limitations imposed by small deformation theory versus more complete large deformation formulations, the benefits of one-, two-, and three-dimensional formulations, and the benefits and drawbacks of more complex approaches. The reliability of current methods must be addressed, focusing on how models have been used in the past and how well they agree with case history results.

The fourth topical area that will be included in the Guidelines deals with the role of physical modeling. Physical modeling, such as done using a centrifuge or shake table, is important to help calibrate analytical techniques and validate analytical approaches, augment case history studies, and to define and identify displacement mechanisms not covered by current analysis procedures. The Guidelines will serve to define what is an acceptable physical model. Scale effects will be discussed in light of the combination of model scales and gravitational accelerations suitable for centrifuges and shake tables.

The fifth topical area for inclusion in the Guidelines deals with the utility of laboratory- and field-test-based soil properties. The important soil properties necessary for accurate modeling will be identified. Critical issues from a property standpoint are: 1) what are the important properties, 2) how do we obtain reliable values, 3) how do we account for the level of stress intensity for physical model testing, e.g., low stress level for shake table versus high stress level for centrifuge, and 4) how reliable are the properties determined either by laboratory or field methods.

In addition to the specific topical areas discussed above we plan to include sections that summarize the analytical contributions made by both the Japanese and

U.S. sides during the First and Second Workshops. These summaries will set the stage for where we are going based on what is available currently. The contributions supplied by Working Group 2 to the Guidelines will include recommendations for practicing engineers, recommendations for future research, and a consensual approach towards the development of rational analytical modeling techniques.