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# General Report — Session 9

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# PERFORMANCE BASED DESIGN IN GEOTECHNICAL EARTHQUAKE ENGINEERING: GENERAL REPORT ON SESSION 9

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## INTRODUCTION

This general report focuses on the eight papers accepted for the session 9. The theme of the session is "Performance based design in geotechnical earthquake engineering". The methods commonly adopted for analyzing the seismic adequacy of existing and new buildings are based on allowable stress design (ASD) and load and resistance factor design (LRFD). Both these design philosophies try to ensure that the load and the deformation in the individual structural elements are within the permissible limits. Whereas the performance based design tries to ensure the entire facility will perform in some predictable way in terms of safety and functionality. The seismic aspects for this performance based design are termed as the performance based earthquake engineering (PBEE). Thus PBEE will try to address the performance at system level considering seismic effects like risk of collapse, repair cost, fatalities etc.

The papers for this session originate from six countries and cover a wide range of topics related to application of performance based techniques in geotechnical earthquake engineering. The topic of the papers which are being presented in this session includes ground improvement techniques, analysis of behavior of piles and the liquefaction potential evaluation. The details of the list of papers for this session are given in a tabular form followed by a brief summary of each paper.

| Paper | Origin | Authors | Topic |
|---|---|---|---|
| 9.02 | USA | J. Tanner Blackburn, Joseph A. Pastore, Richard C. Wakeman, Thomas J. Morgan and Alan T. Evenson. | Compaction Grouting for Seismic Mitigation of Sensitive Urban Sites |
| 9.04 | Iran | Mohammad Hassan Baziar and Amir Hossein Ghaderinia | Evaluation of Seismic Demand of Pile Foundation for Performance Based Design |
| 9.06 | USA | Thomas Oommen and Laurie G. Baise | A Practical Approach for Implementing the Probability of Liquefaction in Performance Based Design |
| 9.07 | USA | Scott J. Brandenberg and Pirooz Kashighandi | Application of Concave-Up P-Y Elements in Static Analysis of Piles in Laterally Spreading Ground |
| 9.08 | Canada | Yasser Abdelghany and Hesham El Naggar | Monotonic and Cyclic Behaviour of Helical Screw Piles Under Axial and Lateral Loading |
| 9.09 | India | T.G. Sitharam and K.S. Vipin | Liquefaction Potential Evaluation Based on Site Classes – A Performance Based Approach |

| Paper | Origin | Authors | Topic |
|---|---|---|---|
| 9.10 | Taiwan R.O.C | Jiunn-Shyang Chiou and Cheng-Hsing Chen | Displacement Ductility Capacity of Fixed-Head Piles |
| 9.11 | Japan | Ramez Alchamaa and Mitutoshi Yoshimine | Simulation on Post-Liquefaction Deformation Considering the Seepage of Pore Water After an Earthquake |

SUMMARY OF RESEARCH PAPERS

*Paper No. 9.02***:** COMPACTION GROUTING FOR SEISMIC MITIGATION OF SENSITIVE URBAN SITES by J. Tanner Blackburn, Joseph A. Pastore, Richard C. Wakeman, Thomas J. Morgan and Alan T. Evenson.

This paper describes the implementation of compaction grouting system for seismic hazard mitigation in an urban area. Densificatioin of soils is one of the most widely used technique for liquefaction mitigation. This paper suggests the use of compaction grouting for soil densification in the urban areas where the vibro-densification methods are not suitable. A case study is done for a site which is adjacent to existing buildings (including an MRI facility). Subsurface exploration was done to obtain the soil profile for the proposed site. The maximum expected earthquake acceleration values were obtained from USGS and the factor of safety against liquefaction was calculated using the CPT values obtained from the site investigation. During the compaction grouting, a field testing program was done for measuring the ground displacement and quality control was done using a 3D visualization systems. The ground improvement has increased the factor of safety against liquefaction and decreased the potential liquefaction settlement. The analysis of the vibration levels also indicated that they were well with in the permissible limits. This paper suggests compaction grouting as an alternative to drilled shafts or driven piles for potentially liquefiable sites.

*Paper No. 9.04***:** EVALUATION OF SEISMIC DEMAND OF PILE FOUNDATION FOR PERFORMANCE BASED DESIGN by Mohammad Hassan Baziar and Amir Hossein Ghaderinia.

This paper discusses the development of correlations between the ground motion intensity measures and the engineering demand parameters on pile foundations. In the performance based earthquake engineering design, the seismic performance is measured with respect to the demand of engineering systems during a seismic event against the conventional factor of safety approach. This paper investigates the effects of two of the intensity measures, peak ground velocity (PGV) and peak ground acceleration (PGA) with engineering demand parameters. It was found that the peak ground velocity (PGV) correlates with the peak strain in a better way than the peak ground acceleration (PGA). In addition to this PGV predicted the damage dissipation energy magnitude more accurately. Further studies are recommended to evaluate the effectiveness of various intensity measures.

*Paper No. 9.06***:** A PRACTICAL APPROACH FOR IMPLEMENTING THE PROBABILITY OF LIQUEFACTION IN PERFORMANCE BASED DESIGN by Thomas Oommen and Laurie G. Baise.

This paper discusses a method for implementing the probability of liquefaction in performance based design. Even though the probabilistic models are better suited for performance based design, there are little studies done till now to evaluate the threshold liquefaction probability values. This study tries to develop this threshold liquefaction probability values based on both deterministic and probabilistic approaches. The study was done using the SPT and CPT data collected from liquefied and non liquefied sites. These were 196 case histories of SPT data base and 182 events were there in the CPT data base. The threshold liquefaction values were evaluated by considering the cost associated with risk and the risk mitigation. For evaluating the threshold liquefaction potential, the liquefaction potential analysis of the samples were done using the conventional simplified liquefaction potential evaluation method and based on latest probabilistic methods. This work comes up with different threshold probability of liquefaction for different methods of liquefaction potential evaluation.

*Paper No. 9.07*: APPLICATION OF CONCAVE-UP P-Y ELEMENTS IN STATIC ANALYSIS OF PILES IN LATERALLY SPREADING GROUND by Pirooz Kashighandi and Scott J. Brandenberg

This paper presents the results of a static lateral spreading analysis of a pile group in concave p-y materials. Most of the static analysis will scale down the characteristic drained loading of the concave down p-y curves and there for missing the pile response. The results obtained in this study indicate how this can lead to unrealistic results. This paper comes to the conclusion that the permanent ground displacements accumulate mainly during the time of high excess pore water pressure, and not during the time of dilatancy. The increase in

shear strain during dilatancy cycles is small due to the temporary increase in stiffness of the liquefiable sand.

*Paper No. 9.08*: MONOTONIC AND CYCLIC BEHAVIOR OF HELICAL SCREW PILES UNDER AXIAL AND LATERAL LOADING by Yasser Abdelghany and M. Hesham EI Naggar.

This paper describes the analysis of monotonic and cyclic behavior of helical pile foundation systems. The testing was done on more than one hundred piles including plain helical screw piles. These piles were subjected to axial and lateral monotonic and cyclic loading. The relations between the installation torque and the ultimate capacity of piles were evaluated in this study. This paper also gives the details of the newly developed cyclic loading full scale test setup for axial and lateral cyclic testing. Attempts to develop new helical screw systems, which can be used for seismic retrofitting of existing and new buildings, were also done in this study.

*Paper No. 9.09*: LIQUEFACTION POTENTIAL EVALUATION BASED ON SITE CLASSES: A PERFORMANCE BASED APPROACH by T.G. Sitharam and K.S. Vipin

This paper explains the methods adopted for the evaluation of liquefaction potential of a vast region (South India) based on SPT values and the site classes. The seismic hazard for the region was evaluated using probabilistic seismic hazard analysis (PSHA). From the peak horizontal acceleration (PHA) values at bed rock level, the surface level peak ground acceleration (PGA) values were evaluated for site class – D. The liquefaction hazard curves were developed for the entire study area by taking a grid size of 11 km x 11km. This liquefaction hazard curves were developed by deaggregating the seismic hazard into different magnitude-acceleration bins. From these liquefaction hazard curves, the SPT values required to prevent liquefaction for a return period of 475 and 2500 years were evaluated using a performance based approach. This paper explains the entire methodology adopted in evaluating the liquefaction potential based on probabilistic performance based approach.

*Paper No. 9.10*: DISPLACEMENT DUCTILITY CAPACITY OF FIXED-HEAD PILES by Jiunn-Shyang Chiou and Cheng-Hsing Chen

This paper deals with a parametric study of the displacement ductility capacity of fixed head piles. The analysis is done based on a Winker – Beam model, in which the pile is modeled as a beam and the soil reactions are modeled using springs. The variables considered in the analysis includes, axial force, the pile diameter, the longitudinal reinforcement ratio and the stiffness of the soil. It was found from the study that the displacement ductility capacity of a fixed head pile is influenced by the axial force, pile diameter and the steel ratio. It was also found that when the sectional over strength ratio of pile is very low, the influence of soil stiffness is less. While evaluating the displacement ductility capacity of a fixed-head pile, the sectional over-strength ratio is more important than the curvature ductility capacity.

*Paper No. 9.11*: DETERMINATION OF THE PROPER THICKNESS OF SUBLAYERS FOR ANALYZING POST-LIQUEFACTION DEFORMATION ASSOCIATED WITH SEEPAGE OF PORE WATER AFTER EARTHQUAKE by Ramez Alchamma and Mitsutoshi Yoshimine.

This paper describes a new approach for estimating the approximate thickness of the sub-soil layers for simulating the post liquefaction behavior. This study has found that the post liquefaction deformation is being controlled by permeability coefficients and its contrast with in the soil layers. It was found that the trend of shear deformation after the earthquake shaking can be captured in centrifuge tests and the setting of the size of the sub-layers in the analysis is a key factor in evaluating the possible magnitude of deformation. It was also found that the number of layers with in a liquefied sand is dependent on the initial relative density of the soil. With increase in relative density the number of sub-layers with in the liquefied soil also increases.

## FINAL REMARKS AND TOPICS FOR DISCUSSION

The topic of the papers presented in this session varied from experimental works for seismic hazard mitigation to numerical techniques for liquefaction potential evaluation. All the papers presented in this session show the high dedication and technical expertise of the authors.

A few topics given below for the discussion are supposed to help the authors and other participants to interact with each other and share their thoughts.

## SUGGESTED LIST OF TOPICS FOR DISCUSSION

- Ground improvement techniques for liquefaction mitigation.
- Techniques for vibration isolation during soil densification.
- Effects of seismic loading of piles and pile groups.
- Probabilistic and performance based analysis of liquefaction potential.
- Different methods of post liquefaction seepage analysis.
- Factors affecting the lateral spreading and its influence on pile strength.