The Effects of Vibration on the Penetration Resistance and Pore Water Pressure in Sands

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Dissertation Submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Civil Engineering

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July 28th, 2000
Blacksburg, VA

Keywords: Vibration, Cone Penetration Testing, Soil Dynamics, Liquefaction, Pore Water Pressure

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(Abstract)

The current approach for using cone penetration test data to estimate soil behavior during seismic loading involves the comparison of the seismic stresses imparted into a soil mass during an earthquake to the penetration resistance measured during an in-situ test. The approach involves an *indirect* empirical correlation of soil density and other soil related parameters to the behavior of the soil during the loading and does not involve a direct measurement of the dynamic behavior of the soil in-situ. The objective of this research was to develop an approach for evaluating the in-situ behavior of soil during dynamic loading *directly* through the use of a vibrating piezocone penetrometer.

Cone penetration tests were performed in a large calibration chamber in saturated sand samples prepared at different densities and stress levels. A total of 118 tests were performed as part of the study. The piezocone penetrometer used in the investigation was subjected to a vibratory load during the penetration test. The vibratory units used in the investigations were mounted on top of a 1m section of drill rod that was attached at the lower end to the cone penetrometer. Pneumatic impact, rotary turbine, and counter rotating mass vibrators were used in the investigation. The vibration properties generated by the vibratory unit and imparted into the soil were measured during the penetration test by a series of load cells and accelerometers mounted below the vibrator and above the cone penetrometer, respectively. The tip resistance, sleeve friction and pore water pressure were also measured during the test by load cells and transducers in the cone itself.

The vibration and cone data were compiled and compared to evaluate the effect of the vibration on the penetration resistance and pore water pressure in the soil mass. The results of the testing revealed that the influence of the vibration on the penetration resistance value decreased as the density and the mean effective stress in the soil increased, mainly because the pore water pressure was not significantly elevated throughout the entire zone of influence of the cone penetometer at the elevated stress and density conditions. An analysis of the soil response during the testing resulted in the generation of a family of curves that relates the soil response during the vibratory and static penetration to the vertical effective stress and density of the soil. The data used to generate the curves seem to agree with the proposed values estimated through the empirical relationship. An evaluation of the effects of the frequency of vibration was also performed as part of the study. The largest reduction in penetration resistance occurred when the input vibration approximated the natural frequency of the soil deposit, suggesting that resonance conditions existed between the input motion and the soil. An energy-based approach was developed to compare the energy imparted into the soil by the vibrator to the energy capacity of the soil. The input energy introduced into the soil mass prior to the reduction in penetration resistance agrees well with the energy capacity of the soil, especially in tests at the low effective stress level where a high excess pore water pressure was observed.

Acknowledgements

I have discovered over my tenure here at Virginia Tech that doctoral research and dissertation writing are tests of intellectual and physical endurance. Surprisingly, I likened the experience to my old scholastic and collegiate wrestling days, where the only way to survive was through the difficult task of perseverance. I thank God for the stamina and the courage to endure the process.

I would like to express my sincere gratitude to my advisor, Professor Jim Mitchell for providing me with the opportunity to work with him on this project. I have benefited greatly from his vast wealth of academic and consulting experience and his never-ending desire to always put his students first.

I would also like to thank my second advisor, Professor Tom Brandon, for providing insight, guidance, and friendship throughout my stay here at Virginia Tech. I have benefited immensely from his ability to generate practical solutions to difficult theoretical problems, no matter the situation, time, or place.

I also appreciate the help of my Virginia Tech advisory committee, Professors Jimmy Martin and Chris Haycocks for taking the time to serve on my research committee. I would also like to thank Professor Paul W. Mayne of Georgia Tech for his technical input and donation of equipment throughout the many stages of the project.

The primary financial support for the project was from the National Science Foundation and the U.S. Geological Survey. Fabseal Industrial Liners of Shawnee, OK, ARA Associates of Royalton, VT, Georgia Tech Department of Civil and Environmental Engineering of Atlanta, GA, Fugro Geosciences of Houston, TX, and Goodyear Tire of Radford, VA, all donated time, money, and equipment to the project. Their efforts are gratefully acknowledged.

A large portion of the work performed on the project involved calibration chamber testing in the Prices Fork Laboratory. Since the pervious research study involving the calibration chamber was performed more than 12 years ago, a significant amount of time and effort went into rehabilitating the chamber and developing a reliable and repeatable testing format. J.T. McGinnis devoted a lot of time and effort into these early stages of the work without ever benefiting from the satisfaction of a usable test. His patience and dedication is greatly appreciated.

David Plehn, Randy Wirt, Youngjin Park, Joe Clarke, and Jim Hawkins aided in and then took over the calibration chamber testing portion of the research project. The dedication of these individuals to high quality work in frustrating and physically demanding situations made the completion of this work possible.

The experimental nature of the research project involved the design and construction of many accessory pieces of equipment. The Virginia Tech technical staff of Clark Brown, Brett Farmer, and Dennis Huffman aided in the construction of many pieces of this equipment. Jim Coffey, with his mastery of the lathe and his uncanny ability to fit a square peg in a round hole, constructed the saturation system in the calibration chamber and built one of the vibratory units used in the testing. The works of all of these individuals are greatly appreciated.

I would like to thank Judy Brown, Judy Dumin, Mary Hunter, and Vicki Graham for their help with all of the administrative and financial matters that I encountered. I would also like to thank Schnabel Engineering Associates, in particular Drs. Ray Martin and Gordon Matheson, for their support of my academic endeavors and the realization that short-term interests do not always outweigh long-term rewards.

My academic and personal stay at Virginia Tech was enriched through the interaction with the following people: Andy Babish, Chris and Diane Baxter, Harry Cook, Mike Donnelly, Russell Green, Matt Helmers, James Kellogg, Jeff McGregor, Brian Metcalfe, Miguel Pando, Carmine Polito, James Schneider, C.J. Smith, Dee Dee Watson, Craig Wise, and Jen Woods. I especially want to thank my colleague, friend, mentor, and true advisor, Jesús Gómez, for his wisdom and thoughtful insight throughout the many stages of my research.

I am extremely grateful to the love and support offered by my brother, Michael, his wife, Jennifer, my sister, Andrea, her husband Mike, and my continually expanding group of nieces and nephews, Tyler, Michael, and Marisa.

Most importantly, I would like to thank my Mother and Father, Connie and John, for their never ending encouragement, support, and love throughout every stage of my life. This work is dedicated to them.

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