Development of a MEMS-Based In-Place Inclinometer-Accelerometer Array for Monitoring and Evaluation of Geotechnical Systems

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ABSTRACT

Real-time monitoring of civil infrastructure provides valuable information to assess the health and condition of specific associated systems. An important effort for the future of civil engineering is thus the development of instrumentation capable of accurate real-time monitoring of geotechnical systems. The use of Micro-Electro-Mechanical Systems (MEMS) accelerometers in geotechnical instrumentation is relatively new but on the rise. This thesis describes a new MEMS-based system for in situ deformation and vibration monitoring. The system has been developed in an effort to combine recent advances in the miniaturization of sensors and electronics with an established wireless infrastructure for on-line geotechnical monitoring. The concept is based on triaxial MEMS accelerometer measurements of static acceleration (angles relative to gravity) and dynamic accelerations. The dynamic acceleration sensitivity range provides signals proportional to vibration during earthquakes or construction activities. This MEMS-based in-place inclinometer system utilizes the measurements to obtain three-dimensional (3D) ground acceleration and permanent deformation profiles up to a depth of one hundred meters. Each sensor array, which can be used vertically or horizontally, or group of arrays can be connected to a wireless earth station to enable real-time monitoring as well as remote configuration. This thesis provides a technical assessment of MEMS-based in-place inclinometer systems for geotechnical instrumentation applications by reviewing the sensor characteristics and providing small- and full-scale laboratory calibration tests.

Descriptions and validations of recorded field data from a bridge replacement site and two unstable slopes are included. This new instrumentation system was also included in full-scale laminar box tests of level and sloping saturated fine sand deposits. These full-scale tests provided a means of evaluating measured acceleration data. In all cases, data recorded with the developed in-place inclinometer system is compared to data measured with state-of-the-practice instrumentation. These comparisons were extremely favorable and justified the future use of this instrumentation for many geotechnical applications. This study also includes a practical evaluation of commercially available geotechnical software predictions as compared to measured site data.