In Situ Calibration of Dynamic Pore Pressure Transducers

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Introduction

In December 1989 tests were carried out at the Wildlife site in Imperial Valley, California to assess the state of several pore pressure transducers which had been installed at various depths in a potentially liquefiable site in 1983 by the United States Geological Survey (USGS) (Bennett, et al., 1984). The site had been observed to liquefy in previous earthquakes, in particular in the Westmorland M_W 5.9 earthquake of 26 April 1981, and was a candidate for an experiment to investigate the transient behavior of soil pore water pressures, developing as a result of strong ground motion. On November 24, 1987, the site was shaken by first the M_W 6.2 Elmore Ranch earthquake and, a short time later, the M_W 6.6 Superstition Hills earthquake. Only small pore pressure changes developed from the first event, but the second earthquake caused significant pore pressure rises in several of the transducers (one exhibited anomalous behavior during the earthquake) (Brady, et al., 1989). The pore pressure changes with time were qualitatively different from those experienced at other test sites (Ikuta, et al., 1979; Ishihara, 1981; Ishihara, et al., 1981, 1987; Harp, et al., 1984; Shen, et al., 1989), and this behavior gave rise to the proposal to check the condition of the transducers and recording system. The results of the assessment tests have been presented and discussed in the literature (Earth Technology, 1991; Hushmand, et al., 1991, 1992; and Youd and Holzer, 1994).

One suggestion which resulted from the study was that it would be desirable to develop a standard procedure for testing current and future dynamic pore pressure installations in the field, after placement, and preferably, at regular intervals thereafter. Such a research site, instrumented with accelerometers and pore pressure transducers, is expensive to establish and maintain, and maintenance will probably have to continue for years before sufficiently strong ground motion occurs to trigger the system and generate pore pressures large enough to be interesting. Regular checks would ensure the reliability of the system, and enable faulty transducers and recording equipment to be replaced.

A proposal to this effect was made to the USGS in 1991, was accepted, and given the grant number 1434-92-G-2169. This report describes and discusses the work performed under that grant. It was proposed to test the in-place transducers at two sites established after the Wildlife installation was set up: the Parkfield and Treasure Island arrays, both in California. The Parkfield site was chosen for a pore pressure study because a variety of instrumentation had been installed there in anticipation of a repeat of the M6+ sequence of earthquakes occurring at the site approximately every 22 years (Holzer, et al., 1988), with the last event in 1966. The large investment in the site made available recording equipment and a maintenance budget for the dynamic pore pressure transducer array. To date (January 1995) the anticipated earthquake has not eventuated.

Liquefaction was observed at Treasure Island in San Francisco Bay during the 1989 M7.1 Loma Prieta earthquake, and later a site was selected on the Navy Base there for a pore pressure transducer array, which was installed along with a data acquisition system in August, 1991 (de Alba et al., 1994). The site instrumentation and follow-up maintenance and monitoring of transducers at Treasure Island was funded by a grant from the National Science Foundation (NSF) as part of the proposed network of U.S. Geotechnical Test Sites (Benoit and de Alba, 1988). However, after acceptance of the proposal for in-situ testing of the existing pore pressure transducers at Parkfield and Treasure Island sites, the NSF withdrew permission to perform check tests at active pore pressure arrays, and substituted them with tests on Treasure Island adjacent to the NSF test facility. Instead of the transducers at the test array, a variety of pore pressure transducers supplied by the USGS researchers was used for assessment of their performance. It should be noted that a number of the transducers in the array at the NSF Treasure Island site had failed since installation prior to conducting the in-situ dynamic calibration tests described here. The precise state of the pore pressure transducers at the Parkfield site is not known to the present authors, but some of the transducers there are also believed to be inoperable.

The transducer in the probe arrays at Parkfield (USGS) and Treasure Island (NSF) is a Druck 830. It is believed that the failure of some of the transducers was caused by the penetration of

water through the seals protecting the electronics. A new transducer, the Druck 940 with improved sealing, is being used for new pore pressure probes (Bennett, 1995). The Druck 830 was used in the USGS retrievable pore pressure probes used in the present calibration tests.

The pore pressure generation and measurement equipment used in the assessment at the Wildlife site in 1989 was not used; instead a new system was designed and fabricated to be more convenient for field use, and to avoid some of the complexities encountered in calibration and deployment previously. At the Wildlife location, various techniques were devised to stimulate transient pore pressure changes in the sensitive soil layer. They included drilling and casing holes in the ground to the appropriate depth and generating pore pressures both by repeated water pressure shocks from a "popper" apparatus (Ostrom and Kelly, 1977) and by step changes in pressure developed by suddenly connecting the capped hole to an air compressor. Another test involved the use of a front-end loader to lift and drop a heavy weight on the ground surface. Although a complete series of tests was not performed with the last device, its ease and convenience, including minimal site disturbance, indicated at the time that it would be a useful technique to pursue. There was also an advantage in stimulating pore pressure changes in the ground by generating ground motions similar, in some respects, to those produced by an earthquake. Consequently, it was proposed to use such equipment in the Treasure Island tests, utilizing the drilling rig, brought in to install the various pore pressure transducers in the soil, for impact tests. Following the impact tests, another series of experiments at a nearby site involved the use of explosive charges to generate transient pore pressures in the soil.

For these trials, a new pore pressure measuring probe was designed and fabricated at Caltech and was used as the reference transducer for the in-situ dynamic calibration and comparison tests of the different USGS pore pressure transducers. The equipment was mobilized and the field tests were conducted at the Treasure Island site in February 1994.