

**Tuesday 3/14/2017**

**1:15-2:45pm**

**Pile, Shaft and Pier Foundations 3**

Chairs: Aaron Budge, Minnesota State University, Mankato; Allen Cadden, Schnabel Engineering LLC

**Multi-level O-cell Tests on the Instrumented Bored Piles in Mekong Delta**

*Minh H Nguyen, Anand J. Puppala, Ujwalkumar D. Patil, Leila Mosadegh, and Aritra Banerjee, University of Texas at Arlington*

Multi-level O-cell tests were carried out on two strain-gauge instrumented bored piles at the Can Tho Bridge crossing the Hau (Bassac) River in the Vietnamese Mekong Delta. The soil profile consists of about 70 m thick soft, deltaic silty clay deposited on dense to compact sand. The test piles, 2.0 and 2.5 m in diameter, were installed into 87 and 98 m depth, respectively, by a combination of casing the upper length and using bentonite slurry to stabilize below the casing. The lower and upper O cell assemblies in the two test piles were located 2.5 m through 3.0 m and 12 m through 15 m above the respective pile toe level, respectively. The tests were performed in four Stages and the maximum loads applied by the lower and upper O-cells were about 21 and 26 MN, respectively. The measurements indicated that the pile toe stiffness of Pile TP1 was very low. The fit of the q-z Ratio Function shows ratio exponents of 0.2 and 0.1 for Pile TP1 and TP2, respectively. The stress-movement curves at the strain gage level GL1 show no tendency toward an ultimate resistance. The evaluation of the strain-gauge data showed that the pile axial stiffness was a function of the induced strain, ranging from a stiffness of 103 through 85 GN. The average unit resistance of both pile shafts placed in dense sand layer is about 460 kPa.

**Use of the High-Strain Dynamic Testing to Efficiently Design and Construct Bridge Foundations in Glacial Soils**

*Morgan Race, Matthew Glisson, and Bryan Field, Braun Intertec*

The design of driven piles in glacial tills and outwash soils is frequently conservative in regards to pile length and foundation cost and ineffective in accurately characterizing the soil-pile interaction. Technology such as high-strain dynamic testing can be utilized to more efficiently and sustainably design and construct deep foundation systems. High-strain dynamic testing was utilized in a design-build project in the Minneapolis/St. Paul metropolitan area to characterize the properties of the soil-pile interaction and more economically construct the substructure foundations. At each substructure, initial drive and restrike tests were performed on 12 ¾-inch outside-diameter, steel, closed-ended pipe piles driven into glacial soils. The unit side resistances and unit end bearing resistances were determined from wave matching analyses using CAPWAP on restrike and/or initial drive data. The differences in the predicted and measured unit side resistance and unit end bearing resistance in glacial till and outwash soils for driven pile are discussed. For the seven structures currently completed, the actual driven pile lengths varied from 24.9 percent greater to 50.7 percent less than the expected lengths and the driven pile lengths were shortened on average by approximately 3.9 percent corresponding to an overall cost savings of approximately \$98,000.

**Underpinning a Boston Landmark for the Ages: The First Church of Christ, Scientist (TFCCS), The Original Mother Church (TOMC) Foundation Repairs**

*Giuliana Zelada and Sean M. Homem, Simpson, Gumpertz & Heger Inc.*

Dealing with the consequences of lowered groundwater levels and consequent untreated timber pile deterioration in Boston's Back Bay is not uncommon. Urban sprawl in this area in the late 1800s and early 1900s was made possible through land reclamation, filling in the remnants of the old bay. Untreated timber piles were often used as the foundation of choice in these conditions. Unfortunately, urban construction also resulted in decreased groundwater levels as a result of underground construction, leaking utilities, and leaking basements. The Mother Church (TMC), located on The First Church of Christ, Scientist (TFCCS) campus, is a historic landmark in downtown Boston supported on hundreds of untreated timber piles, and has long been implementing a system of movement and groundwater monitoring to identify any areas at risk of timber pile deterioration. In particular, the surveys indicated that the bell tower of The Original Mother Church (TOMC) was at a high risk of having deteriorated timber piles, and test pit investigations confirmed this. To mitigate future settlements, and extend the service life of the structure, we designed and implemented a foundation underpinning and repair scheme consisting of two phases: underpinning of the main tower with steel needle beams and pre-loaded micropiles, and cut-and-post underpinning in the remaining areas of the TOMC. The design and construction of the foundation underpinning had to accommodate for highly congested and restricted access areas, maintain the integrity of the unreinforced masonry tower structure during the load transfer process, incorporate micropiles needed through the forest of timber piles below the tower, and provide for a system with minimal future settlement and a service life in the order of 500 years. The project was completed successfully and on schedule, with minimal adjustments to the contract plan. Follow up movement monitoring surveys shows no additional movement of the TOMC bell tower has occurred.

### **Augered Cast-in-Place Pile Foundation Design and Construction for the MLK Bridge, New Stadium Project, Atlanta**

*Graham Elliott, WSP-Parsons Brinckerhoff; Natale Marini, previously WSP-Parsons Brinckerhoff, now HNTB; Matthew Meyer, Langan Engineering & Environmental Services Inc.; Morgan NeSmith, Berkel & Co. Contractors Inc.*

Augered Cast-in-Place (ACIP) piles were installed for an elevated roadway in the City of Atlanta, as part of the infrastructure improvements for a new stadium project. The design-build project team opted to support the continuous span bridge on groups of 610 mm diameter ACIP piles, principally to avoid noise and vibration issues in the downtown environment. The ground conditions comprised a sequence of fill, Piedmont residual soil and partially weathered rock (PWR), overlying Precambrian metamorphic rocks. Results of two instrumented static load tests on non-production piles demonstrate the axial loads are transferred principally in shaft resistance. Mobilized unit side resistance values of 73 kN/m<sup>2</sup> in the Piedmont residual soil and 199 kN/m<sup>2</sup> in the PWR were derived from strain gauge arrays. For production piling, confirmation of the embedment lengths and grout volumes were key quality control parameters, verified during construction with Automated Monitoring Equipment (AME).

### **General Bearing Capacity Theory and Soil Extraction Method for the Mitigation of Differential Settlements**

*Rozbeh B. Moghaddam and Priyantha W. Jayawickrama, Texas Tech University*

Differential settlements experienced by a number of historic monuments have been remediated using the soil-extraction method. Italy's leaning Tower of Pisa and the Mexico City's Metropolitan Cathedral are two well-known structures where the soil-extraction method was applied to address issues

associated with differential settlements. This paper describes a case study for a seven-story building in Mexico City, where differential settlements generated vertical inclinations ranging from 241-mm (9.5-in) to 310-mm (12.0-in) to the north, and 70-mm (2.75-in) to 98-mm (3.9-in) to the east. For the remediation of these inclinations, the soil-extraction method was applied through rectangular cavities excavated underneath the foundation element. The general bearing capacity theory was used to determine the location and dimensions of these cavities. After finalizing the soil-extraction process, an average settlement and upward movement of 87-mm (3.5-in) and 24-mm (1.1-in) were recorded, respectively. After the completion of the soil-extraction process, all deformations were brought within tolerable limits specified by the local building code.

### **Minimization of Cost and CO<sub>2</sub> Emissions for Strip Footings under Dynamic Loading Using a Big Bang-Big Crunch Algorithm**

*Andrew Assadollahi, Christian Brothers University*

A procedure is developed to minimize cost and CO<sub>2</sub> emissions for the design of reinforced concrete strip footings subjected to dynamic loading, satisfying geotechnical limit states and using a Big Bang-Big Crunch (BB-BC) algorithm. The objectives of this research are to develop low-cost and low-CO<sub>2</sub> emission designs of strip footings when subjected to dynamic loading. Cost is based on materials and labor required for the construction of strip footings. The CO<sub>2</sub> emissions are associated with the extraction and transportation of raw materials; processing, manufacturing, and fabrication of products; and the emissions of equipment involved in the construction process. The cost and CO<sub>2</sub> objective functions are subjected to dynamic soil bearing and dynamic displacement limits. A design example is presented to compare low-cost and low-CO<sub>2</sub> emission designs. Results are presented that demonstrate the effects of different magnitudes of applied dynamic loads for strip footings founded in different types of soils.