

## Dynamic and Static Tests on Driven and Cast-in-Place Piles

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### Abstract

A pile installation and testing program was undertaken at the site of a proposed bridge replacement project in South Carolina, USA. Subsurface conditions at the test site consisted of 14 m of sand and clay, 0.6 m thick caprock layer over a deep underlying stratum of calcareous sand. Three prestressed concrete piles, one steel H-pile and one drilled shaft were studied. All driven piles were dynamically monitored during installation with a Pile Driving Analyzer according to the Case Method. Some piles were also dynamically tested during restrike to evaluate time dependent pile capacity changes. All concrete piles, including the drilled shaft, were additionally tested using the P.I.T. dynamic low strain method for structural integrity assessment. Two of the driven piles were statically load tested to failure. The drilled shaft was tested up to the capacity of the loading system (8900 kN). One of the driven concrete piles was not subjected to a static loading test because of pile damage during installation. The steel pile was not statically tested due to misalignment between the pile head and the reaction system.

This paper presents discussions on the low strain and high strain dynamic testing and static loading test methods along with comparative evaluation of results. Ultimate pile static resistances determined from dynamic tests were within 8% of those measured by full scale static loading tests. Additionally, predicted and measured pile head load-movement and pile shaft forces at ultimate resistance relationships also agreed well. Structural damage in the shaft of one of the driven concrete piles was evident in records of both high and low strain dynamic tests.

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## Introduction

Foundation settlements of more than 300 mm and corresponding structural distress required replacement of the swing span bridge carrying traffic along Highway 802 over Battery Creek in the eastern coastal region of South Carolina, USA. Settlements occurred when the supporting deep foundations (octagonal prestressed concrete piles with steel H-section extensions) punched through the bearing stratum which consisted of a relatively thin limestone caprock. The new replacement structure will be a segmental concrete bridge with a total length of approximately 915 m (including a 43 m long center span) and a width of 26.2 m. Navigational clearance dimensions will be 13.7 m vertical and 18.3 m horizontal near the middle of the bridge.

A pile installation and testing program was undertaken at the project location to determine relevant foundation design parameters and evaluate the performance of various pile types and sizes. The test site location was chosen for its accessibility and convenience in order to minimize the cost of the testing program. A total of five piles of various types and sizes were evaluated. Additionally, four shafts were installed as reaction piles. All test piles were dynamically tested and three were load tested statically. The specific objectives of this preconstruction testing program included: determination of pile installation characteristics, verifying minimum factors of safety against failure, determining pile load-movement behavior, analyzing pile-soil load interaction behavior, and to compare several different pile types to determine which would be the most suitable to satisfy project requirements. This paper presents discussions on pile installations and testing procedures and results.

The original work for this project was done in the English units, soft conversions were used to convert values to the SI units for this paper.

## Subsurface Conditions

Twenty six soil test borings ranging in depth between 10 and 30 m were drilled to explore the subsurface conditions along the proposed bridge alignment. The pile driving and testing site was located on a small peninsula near an approach to the existing bridge. This location was chosen for its convenience allowing for economic accommodation of the test program and its required equipment.

One soil test boring was drilled to a depth of 27.4 m within the confines of the test site. The boring initially encountered a 1.8 m thick layer of firm sandy clay which was underlain by a 3.3 m thick layer of loose silty sand followed by a 1.8 m thick layer of soft plastic clay. At a depth of 7.0 m, a 2.4 m thick layer of loose sand was encountered. The Hawthorn

Formation (very loose to loose very silty sand) was found at a depth of 9.5 m. A thin (approximately 0.6 m) layer of hard, very sandy limestone ("caprock") was encountered at approximately 12.5 m depth. From a continuous coring run of the caprock only one 50 mm long sample was recovered. Due to the insufficient size of this sample, the compressive strength of the caprock could not be determined. A fine to coarse, calcareous sand displaying some cementation was encountered below the caprock and extended to the boring termination depth of 27.4 m. A simplified log of the boring showing soil strata including Standard Penetration Test N-values is presented in Figure 1.

### Test Piles

Three prestressed concrete piles, one steel H-pile and one drilled shaft were studied. Additionally, four drilled shafts (890 mm in diameter) ranging in lengths between 27 and 32 m were installed as reaction-piles for the static loading tests. The piles tested are referred to as Test Piles A, B, C, D and E. Test pile A was a steel HP 14x73 section (area = 138 cm<sup>2</sup>) with a length of 24.4 m. Test Pile B was a 457 mm square (area = 2090 cm<sup>2</sup>) prestressed concrete pile with a length of 19.5 m. Test Piles C and D were 610 mm octagonal (area = 3077 cm<sup>2</sup>) prestressed concrete sections with lengths of 19.5 and 24.1 m, respectively. The 890 mm diameter, 17.7 m long drilled shaft was Test Pile E. Each of the precast concrete piles was cast with a steel "stinger" which extended 0.76 m beyond the tip of the pile. An HP 10x57 section was embedded 1.8 m into the center of the square concrete pile and HP 12x74 sections were embedded 2.3 m into the octagonal piles.

Vibrating wire strain gages were installed at various points in each of the test piles for measurement of pile strains at different sections during static loading tests. Sixteen Geokon model VSM 4000 weldable gages were welded to the web of the H-pile. Gages and leads were protected by steel angles welded on both sides of the web. Geokon Model VCE 4200 gages were tied in the center of the concrete precast piles before casting, and tied to the reinforcing cage of the drilled shaft. Geokon VSM 4000 gages were used to instrument the H-pile extensions. Gages were located at five to seven locations along pile lengths corresponding to the different soil layers. Two gages were used at each location.

Installing the driven piles was accomplished with a Vulcan 520 single acting air hammer. This particular hammer had a ram weight of 89 kN and was fitted with a slide bar allowing for a 0.91 and 1.52 m strokes (corresponding rated energies of 81.6 and 136.0 kJ, respectively). Sheets of plywood with thicknesses ranging between 150 and 300 mm were used as pile top cushions when driving the concrete piles.

























