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Comparison between high strain dynamic and static load tests of helical piles in cohesive soils

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ABSTRACT

Helical piles provides an attractive alternative to conventional pile types such as driven steel open-pipes and concrete piles by improving their axial compressive and tensile resistances. Static load testing is often used to validate helical pile design and as a proof test for production piles. In the current study, the suitability of High Strain Dynamic Testing (HSDT) was investigated. Both helical piles and driven steel open-pipes were installed and high strain dynamic pile load tests were performed on both types. Dynamic pile testing was used to assess static load-bearing capacities of both driven and helical piles. Dynamic data were also used for the determination of Smith soil parameters such as soil quake and damping parameters using CAPWAP signal matching program. Full scale static pile load testing was also performed for both driven pipes and helical piles. The results of static load tests were used to examine the axial capacities obtained using dynamic testing for torque driven helical piles. Examination of the full scale static load test data and CAPWAP analyses suggested that HSDT could provide a suitable tool to assess static helical pile capacities.

1. Introduction

The use of helical piles to support high loads has grown exponentially in the last few years due to their improved performance and construction advantages combined with the development of more robust rotary hydraulic heads capable of installing larger piles. Static capacities of helical piles are typically assessed using theoretical methods such as individual helix method ([14,26]; and [5]) and cylindrical shear method [26,16,6,27]. Static capacities are often validated using relatively time-consuming static pile load tests. For example, the axial compression tests, depending on testing procedure and complexity, may take between one to two working days.

Installation torque–capacity correlation for helical piles, developed by Hoyt and Clemence [13], is another in-situ verification technique, especially for small diameter helical piles. However this torque correlation lacks theoretical background and does not explicitly consider soil profile. Therefore, the need for more robust testing technique, such as high strain dynamic pile testing, to validate pile installation has become an urgent priority with the rapid increase of helical pile use.

High strain dynamic testing method is a widely accepted testing technique for driven piles, and ASTM D4945 [1] is often referenced as minimum test requirements (Rausche et al., 2008). In this method, the static capacities of driven steel piles and concrete piles can be predicted using either pile driving formulas or wave equation analysis, originally proposed by Smith [25]. The pile capacity evaluated based on pile driving formulas, which relate the measured permanent displacement (set) of the pile at each blow of the hammer to the pile capacity, is usually not reliable. The wave equation analysis provides a more rational approach for the estimation of pile load carrying capacity. Because of stress wave effects caused by the rapid loading of the pile, a plot of measured force versus measured displacement does not resemble the static load–settlement curve. For the calculation of the static load–settlement curve, it is necessary to reduce the dynamic force to a static one by removing the dynamic effects of both the pile and soil. Several computer programs based on the basic solution to the one-dimensional wave equation are widely used such as WEAP [22]; TT1, developed by the Texas Transportation Institute and Texas A&M University [12]; CAPWAP (CAse Pile Wave Analysis Program; [22]); and TNOWAVE [15].

The main objectives of the present study are to: (1) to evaluate the suitability of using high strain dynamic testing (HSDT) to helical piles; (2) to explore the use of CAPWAP for signal matching of helical piles; (3) to correlate between static and dynamic test results; and

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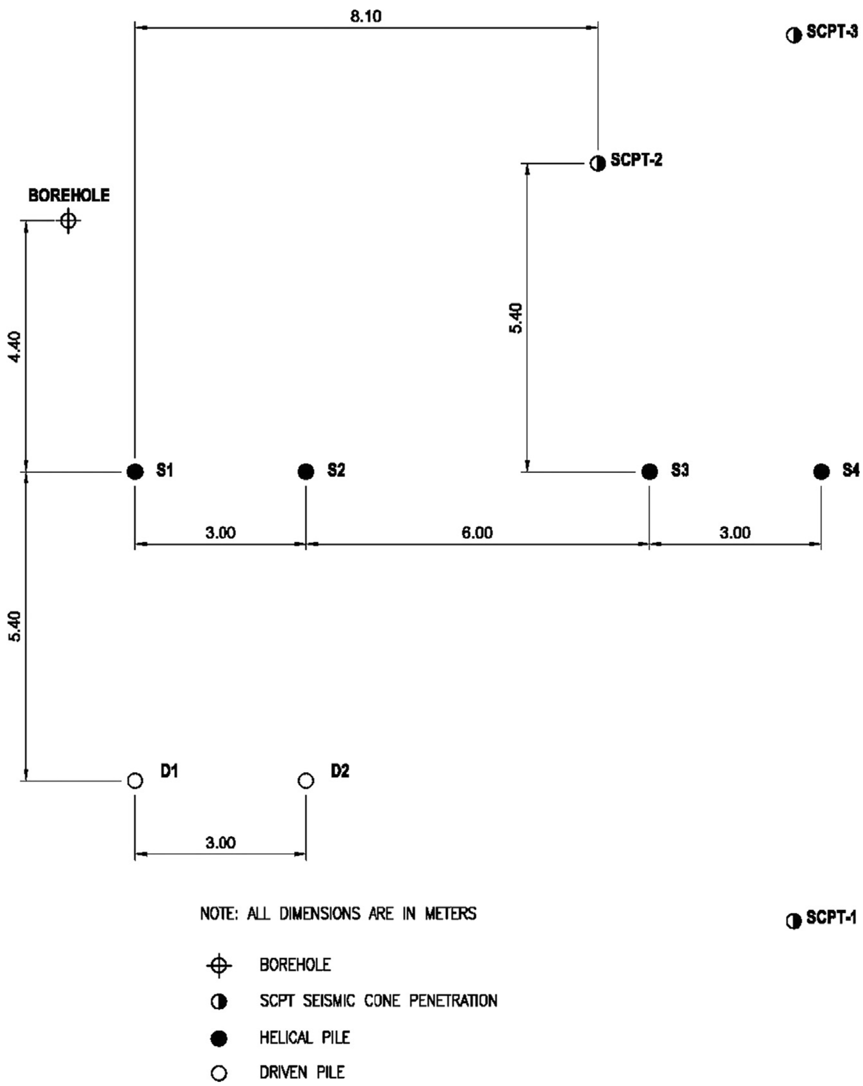

Fig. 1. Location of piles, seismic cone penetration tests, and borehole (need to be revised).

(4) to establish the HSDT requirements for helical piles. The use of HSDT testing for helical piles is likely to improve their acceptance among engineering communities and provide robust and efficient testing tool to validate pile capacities. To date, a limited number of published studies are available in the public domain, such as Cannon [4], who documented several projects where dynamic pile load testing has been successfully used to estimate static compressive capacities of helical piles. Beim and Luna [3] reported the results of HSDT for small diameter helical piles with shaft diameter of 73 mm installed into varved clay. They concluded that HSDT is a viable option for small diameter helical piles.

In order to achieve these objectives, both helical piles and driven piles were installed. Dynamic testing was performed several months after installation, followed by static pile load testing (after about one week). The testing arrangements, soil conditions, site observations, and results are summarized in the following sections.

1.1. Subsurface conditions

The test site is located about 12 km north of the town of Ponoka, Alberta, Canada. The subsurface investigation was performed using seismic cone penetration testing (SCPT) and a geotechnical borehole to a depth of about 15.0 m. Three SCPT sounds and one geotechnical borehole (auger boring only for visual classification of soils) were drilled at approximate locations illustrated in Fig. 1. The stratigraphy and soil properties of the test site are documented elsewhere [8].

CPT sounding at the test location is presented in Fig. 2. Based on the soil investigation program, the average soil profile at the location of the test piles (Fig. 3) consists of a silt layer, approximately 1.3 m deep, over a clay and silty clay layers to a depth of approximately 5.5 m, over glacial till including silty clay and silt lenses that extended to the end of test hole at a depth of approximately 15 m. The clay was brownish in color, silty, and interbedded with seams of silt. The glacial till was very stiff to hard, gray, and silty and contained traces of sand and gravel. Sand lenses were encountered within the clay till layer at different depths. A dense to very dense silty sand/sand to sandy silt layer, 0.5 m thick, was encountered at a depth of approximately 5.5 m. The ground water level was established at 1.2 m below the ground surface.

Soil properties are summarized in Table 1. The in-situ bulk unit weight of the different layers of soil were estimated using the soil classification charts provided by Robertson et al. [23] in combination with the cone tip resistance and friction ratio, corrected for the effect of pore pressure. The distribution of shear wave velocity, V_s, was obtained from the measurements of the SCPT and from the established empirical correlations in terms of N values. The values of the small-strain undrained Poisson's ratio, ν, were obtained from the V_s and V_p measurements and were found to vary between