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Lessons learned from large-scale physical modeling of tapered jacking piles: HSDT

Lars Bo Ibsen[1,*], Amin Barari[2]

[1]Department of the Built Environment, Aalborg University, Thomas Manns Vej 23, 9220 Aalborg, Denmark
[2]School of Engineering, Royal Melbourne Institute of Technology, Melbourne VIC 3001, Australia
* Corresponding author: lbi@build.aau.dk

To provide an improved understanding of the behavior of screw piles in disturbed soil, as a series of companion papers, laboratory tests with full scale tapered jacking piles were performed in the current study. The designated tapered pile has the similar dimensions, material properties and cone-shaped bottom, with the exception of threads eliminated.

The main objectives of this paper are to: (1) establish the robust and efficient simple high strain dynamic testing (HSDT) requirements for validating displacement tapered piles capacities while exploring the installation effect; (2) determine a correlation between static and dynamic bearing capacity in compression for steel tapered piles installed by jacking in sand with various relative densities.

Out of nine large-scale laboratory expriments at Aalborg University Offshore Geotechnics Laboratory [1-3] with the tank filled with Aalborg University Sand No.1, this research exclusively presents some lessons learned from an exemplar tapered jacking pile installation (Test 4) in dry sand (relative density $D_r = 73\%$) and its response to monotonic and impact loadings. The selected piles have diameter of D=76 mm and 89 mm with length of 2.07 m. The layout of the miniature CPTs carried out to measure soil state is shown in Fig. 1, with four CPTs performed following each jacking installation campaign to study the soil state after the installation of the piles (Fig. 1). In order to fulfill the objectives, the piles are installed by a static compression load that includes an unloading/reloading step, followed by dynamic testing in order to facilitate the determination of the bearing capacity (Fig. 2). The hammer test was carried out on both piles, by a hammer from increasing drop heights of 218, 418, 618, 818 and 1018 mm (Fig.3). The hammer consists of a sleigh with multiple attached steel plates weighting 19.31 kg on average and the sleigh itself weighs 18.55 kg. Tapered pile jacking resulted in dilation extending to a depth of $2.8D_{pile}$ when diameter exceeds from 76 mm to 89 mm. By contrast, in the region around pile P76, the soil was entirely densified. The tendency to densify the soil near tip area due to jacking installation is observed in both tests, where the initial viod ratio varied from 0.67 to 0.59 and from 0.63 to 0.57 corresponding to piles P76 and P89, respectively (Fig.4).

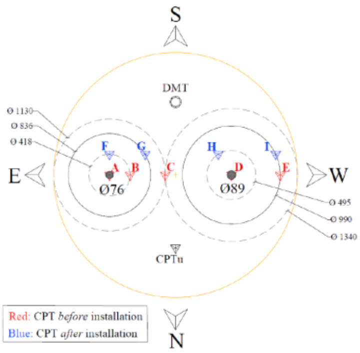

Figure 1: An overview of the miniature CPT tests perfomed for P76 and P89, , Ø [mm].

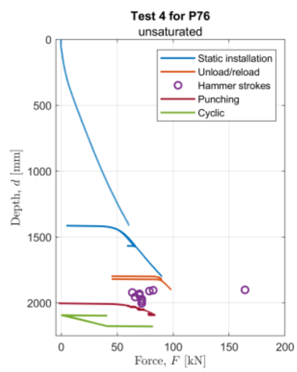

Figure 2: Measured axial compression load test response resulting from static and impact loading (pile P76: test 4).

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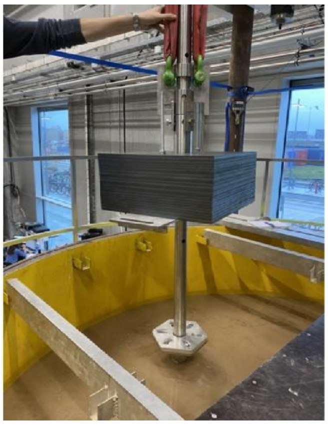

Figure 3: HSDT tetsing configuration

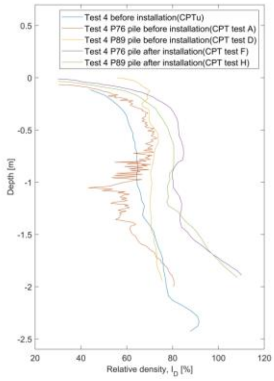

Figure 4: Relative densities prior to and post installation for Test 4 determined from a single CPTu test and selected CPT tests.

Subseuqntluy, Danish Pile Driving Formulas (DDR) introduced by [4] was ustilised which is according to the required potential energy from a hammer stroke to exceed the pile penetration resistance. The mass of the hammer *G* is defined by:

$$G = \frac{R_s s + 0.5 s_0}{\eta h_{drop}} \tag{1}$$

where elastic settlement $s_0 = \frac{R_s l_p}{A.E_{steel}}$, *A* is cross-sectional area, *E* is the Young's modulus, *l* is the installed length of pile which is approximately 1.9 m, and R_s is the maximum static force required to install the pile. The efficiency factor η is set as 1. During the impact loading tests, the settlement of the pile is measured with a 1 mm accuracy for each hammer stroke, and the limiting settlement, *s* was set to yield a certain level (0.1D) when the drop height h_{drop} is 618 mm. Thus, the dynamic bearing capacity $R_d = (\eta h_{drop} G)/(s + \frac{1}{2} s_0)$, R_s and ratio=R_d/R_s are shown in Table 1.

Table 1. Summary of static and dynamic bearing capacity for P76 and P89

Test no.	Static bearing capacity R_s [kN]	Dynamic bearing capacity R_d [kN]	Ratio
P76-4	89	64.5	0.7
P89-4	123.4	83.8	0.68

Data Availability Statement

All of the data, models, or code generated or used during the study are available from the corresponding author by request.

Contributor statement

Lars Bo Ibsen: Testing, Conceptualization, Methodology, Writing; Amin Barari: Testing, Conceptualization, Methodology, Writing.

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