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Evaluation of installation effects on the set-up of field displacement piles in sand
by

Ivana Anusic, Barry M. Lehané, Gudmund R. Eiksund, and Morten A. Liingaard
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Discussion by

Gholamreza Mesri¹ and Thierno Kane²

In connection to post-densification penetration resistance of a sand deposit in Jebba, Nigeria, which had been densified by vibrocompaction at the upper 25 m and by blasting at the 25-40 m depth, Mesri et al. (1990) proposed the following interpretation for the observed increase in penetration resistance with time. The sand particles continue to rearrange after any process of disturbance with a net void volume decrease. An improved resistance to deformation develops with time, with a gradual increase in sliding resistance through microinterlocking of sand particles surface roughness and increased geometrical grain interference through more efficient packing. Mesri et al. (1990) illustrated sand grain surface roughness by Scanning Electron Micrographs (SEM), which has been confirmed by SEM of other natural sands (Mesri and Vardhanabhuti, 2007).

In the Jebba experience, several days after densification, cone-penetration resistance was less than the original value even though ground surface settlements totaling 0.3-1.1 m were measured immediately following the blast coverages. This means significant disturbance of sand structure through the disengagement of sand grain surface roughness at interparticle contacts. Substantial increases in penetration resistance developed through engagement of sand particles surface roughness at the post-densification interparticle contacts over an observation period of

¹ Ralph B. Peck Professor of Civil Engineering, University of Illinois at Urbana-Champaign, Urbana, IL 61801
E-mail for correspondence: gmesri@illinois.edu

² Graduate Student, University of Illinois at Urbana-Champaign, Urbana, IL 61801

weeks to months after blasting or vibrocompaction while porewater pressures remained constant and ground surface settlements were negligible.

Mesri et al. (1990) proposed the following equation to interpret the observed postdensification increase in cone tip resistance

$$(D1) \quad \frac{q_c}{(q_c)_R} = \left(\frac{t}{t_R} \right)^{C_D \cdot C_\alpha / C_c}$$

Where $(q_c)_R$ is a reference cone resistance at a reference time $t_R > t_p$, q_c is cone resistance at any time $t > t_R$, t_p is time required for dissipation of densification-induced porewater pressures, C_α/C_c is a measure of secondary compressibility with values for sands in the range of 0.02 ± 0.01 (Terzaghi et al. 1996, Table 16.1), and C_D reflects the potential for the increase in interparticle resistance, and is directly related to degree of sand structure disturbance during densification. The values of C_D for the Jebba experience were in the range of 9 to 20, and in general, increased with $\Delta e_R = \Delta e / (e_{\max} - e_{\min})$ where Δe is the decrease in void ratio during densification.

In a previous discussion of post-installation increase in the shaft capacities of driven piles in sand, Eq. D1 was used in the following form (Mesri and Smadi, 2001)

$$(D2) \quad \frac{Q}{Q_R} = \left(\frac{t}{t_R} \right)^{C_D \cdot C_\alpha / C_c}$$

Where Q is the pile capacity measured at time t after driving, and Q_R corresponds to $t_R = 1$ day after pile installation. The time-dependent pile capacity reported by Chow et al. (1997) were compared to Eq. D2 with $C_\alpha/C_c = 0.02$ and C_D in the range of 4 to 12. The magnitude of C_D in Eq. D2 reflects the degree of disturbance of sand deposit during pile installation, as well as type of sand characterized by particle size, particle shape, particle crushability, gradation, and plastic fines content. Equation D2 does include the increases in the strength and stiffness of the sand mass

around the pile and the increase in radial effective stress; however, it does not include increase in corrosion of pile or bonding of sand particles to pile surface.

The data in Table 3 of Anusic et al. (2019) correspond to different pile installation procedures in different types of sands and field conditions. For one sand type and installation method at one site, there are not enough data to evaluate pile capacity as a function of time; and for example, examine the behavior of C_D with elapsed time after pile installation. In one location in Jebba, Eq. D1 with a constant value of $C_D = 10.3$ fitted the measured q_c data over a period of 120 days (Mesri et al. 1990 in Fig. 13). In Fig. D1, Eq. D2 with constant values of C_D in the range of 1 to 9 has been superimposed on the pile capacity data in Fig. 1 of Anusic et al. (2019). Although in one location in Jebba, Eq. D1 accurately predicted push cone penetration resistance over a period of 120 days, the predicted rates of ongoing increase in pile shaft capacity with time by Eq. D2 in Fig. D1 beyond 1000 days may be unrealistic.

In summary, pile installation procedure, together with sand type, is expected to determine the magnitude of C_D and pile capacity with time. For any type of sand, pile installation procedures that involve insignificant sand structure disturbance result in small values of C_D and insignificant increase in pile capacity with time. On the other hand, pile installation procedures that cause significant disturbance of sand structure, correspond to large values of C_D and significant increase in pile capacity with time.

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Figure D1. Comparison of Eq. D2 with pile capacity measured with time. Data from Anusic et al. (2019)