Ageing Effect on Pull-Out Capacity of Driven Micropiles in Dunkirk Sand

Imane Salama[1(✉)], Christophe Dano[1], Matias Silva[1,2], and Miguel Benz Navarrete[3]

[1] Univ. Grenoble Alpes, CNRS, Grenoble INP, 3SR, 38000 Grenoble, France
{imane.salama,christophe.dano}@3sr-grenoble.fr
[2] Department of Civil Engineering, Universidad Tecnica Federico Santa Maria, Valparaiso, Chile
[3] Sol Solution Company, BP 178, ZA des Portes de Riom Nord, 63204 Riom, France

Abstract. In order to better understand the origin of ageing on driven micropiles in sand, a series of field pull-out tests on small diameter driven piles were carried out in Dunkirk. The micropiles were about 51 mm in diameter, 8 mm wall thickness and 2 m embedment. The micropiles were made of different steel types (mild steel or stainless steel) with different shaft roughness. Sand characteristics, field penetrometer tests and pile tests are summarized. Tension tests were performed at different intervals of time after micropiles installation in attempt to investigate the influence of: (i) physiochemical effects, by testing both stainless and mild steel piles; (ii) the early stages of ageing. A significant increase of capacity was observed in the case of mild steel micropiles, regardless of the shaft roughness, while no ageing effects were observed on stainless steel micropiles. Some micropiles have been pre-loaded in compression at different energy levels. These results suggest the great influence of physiochemical effects (corrosion) for small diameter piles driven in sand. In the case of a prior compressive plastification, the loss of the benefit of ageing is obvious.

Keywords: Ageing · Sand · Micropiles

1 Introduction

The substantial increase of soil properties and bearing capacity of geotechnical structures with time, independently of any consolidation process, refer to the ageing process. An increase of both stiffness and strength of sand specimens with time, under constant effective stress, was showed by Daramola [2] through triaxial tests. Despite several investigations [1, 3, 5, 9, 10], the origin of ageing remains an open question. Three possible mechanisms [5] behind this phenomenon are suggested: (i) higher stationary radial effective stresses acting on pile shaft and induced by the stress redistribution; (ii) dilatative shaft radial stress contributing to growth in capacity [1, 8]; and (iii) physiochemical processes such as corrosion [11].

In the aim of better understanding these mechanisms in sands, a series of field pull-out tests on small diameter open-ended driven piles has been carried out in Dunkirk (France). A summary of the soil parameters [5, 6] is shown in Table 1. Dynamic penetrometer Panda2® carried out in the closeness of micropiles indicated a denser central zone in the pile test area. The tip resistance q_c increased from 0 to 40 MPa from surface to 1.5 m BGL before reducing between 1.8 and 2 m to approximately 35 MPa [7]. Below 1 m a spatial scatter in q_d is observed and it goes below q_c: from 1 to 2 m q_d is about 10 MPa to 25 MPa in the soft zone and about 20 MPa to 40 MPa in the undisturbed zone.

Table 1. Soil parameters and ground conditions.

	Unit	
Water table BGL	m	4–4.7
Description		Dense to very dense
Origin		Marine hydraulic fill
Dry unit weight (γ_d)	kN/m^3	17.5
Water content	%	5–7
S_r	%	25–40
D_{50}	mm	0.26

2 Testing Programme

The testing campaign commenced in January 2016 and was completed in December 2016. 35 steel (mild and stainless steel) open-ended piles were installed. The piles had an Outside Diameter (OD) of 51.0 mm and 50.6 mm (mild steel and stainless steel piles respectively), a wall thickness of 8 mm and 7.5 mm (mild steel and stainless steel piles respectively), and a length of 2.2 m so that the tip of the pile was embedded 2 m BGL. A compact driving machine, the Sol Solution Grizzly tool was used to drive all the piles. The piles were subjected to static load tension tests at intervals of approximately 1, 14, 28, 90, 175, 272 and 315 days after installation, with a loading device comprising: (i) a reaction frame consisting of two IPE 270 steel beams and two HEB 160 steel beams placed on timber plates; (ii) a manual Enerpac hydraulic jack (HBM C6A) inducing tension in the pile; (iii) three Linear Variable Displacement Transformers (LVDT) transducers, HBM WA200 mm. The loading was applied by increments of about 10% of the estimated capacity, each of them being kept constant for 15 min, until reaching the failure of the pile. Failure, here, is considered as the maximum value of the load during the test and the estimated capacity is calculated following the ICP method [4].

3 Results and Conclusions

Smooth mild steel piles showed a tensile capacity of about 30 kN after installation and a clear increase of capacity gradually to a mean value of 70 kN 315 days after driving (see Fig. 1). Nonetheless, the capacity after installation was larger for rough piles (about 50 kN) than smooth ones (30 kN) and it reached higher values at long term (up to 90 kN). After extraction, all the mild steel piles exhibited a crust of sand attached (glued) to the pile shafts. For stainless steel piles, the tension capacity varied in a small scatter from

25 to 30 kN whatever the deadline can be. It does not show any increase as for the mild steel piles. Despite a larger initial roughness, the shot-blasted rough stainless steel piles have almost the same capacities than smooth piles. No crust of sand was observed attached to the pile shaft after extraction (see Fig. 1).

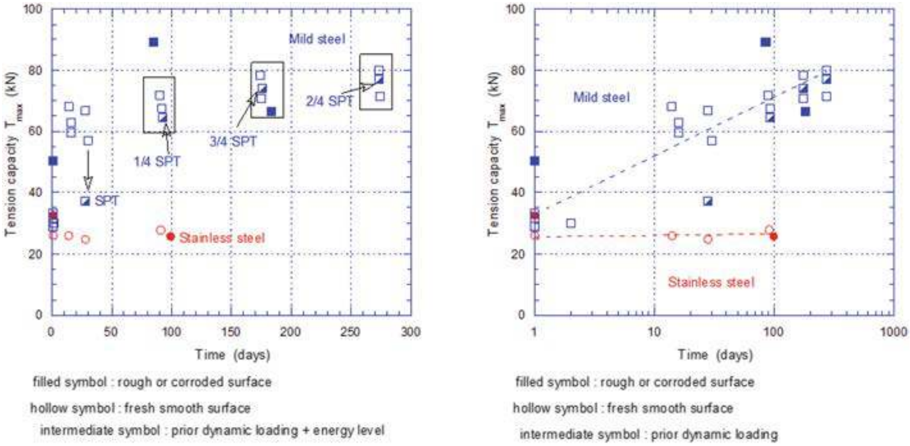

Fig. 1. Evolution of capacity with time.

Obviously, for small piles, physiochemical mechanisms play an important role in the set-up process. Oxidation and cementation that attaches (glues) sand grains to the pile induce a shift of the shearing plane into the sand and increase constrained dilatancy. Effects of chemistry such as corrosion were evident as no ageing was found in stainless piles versus ageing in mild steel piles. Stiffness does not follow a similar evolution.

Some piles were submitted, before tension tests, to a dynamic compressive load and compared to intact piles at the same age of testing, in order to verify the durability of the set-up benefices. Piles re-driven with a fraction of the SPT energy did not present any significant decrease of the tension capacity. In contrast, piles strongly re-driven at the SPT energy level showed an important decrease of their capacity to a value close to the capacity directly after installation (see Fig. 1). Two of these piles were let in place after compression load and re-tested some months later to see if set-up could be re-activated but no evolution of the tension capacity was observed (see Fig. 1).

Acknowledgements. The authors want to acknowledge the partners of the project, Sol Solution company for their interest in the project, their practical help and fruitful discussions. Many thanks to European partners: Prof. Jardine (Imperial College of London), Dr. Carroll and Dr. Carotenuto (Norwegian Geotechnical Institute), Prof. Gavin (TU Delft), as well as Grand Port Maritime de Dunkerque and Dong Energy for the access to the site. Finally, we want to thank 3SR Laboratory (Geomechanics team) for the financial support.

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