# Micropiles in cohesive soils under axial cyclic loading

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Micropiles are technically and economically important foundation elements. Their successful application as foundation reinforcements or underpinnings has been well documented for decades. The safety of these foundations under cyclic loading is of special relevance with anti-buoyancy systems, high structures such as pylons or wind energy plants and noise protection walls, but the knowledge in this scope of interest is considerably less.

Previous research projects showed, that the capacity of micropiles in sands under vertical cycling loading can decrease considerably compared to static loading. Therefore permitted characteristic load ranges were defined in DIN 1054:2005 for micropiles in sand under axial cyclic loads depending upon the bearing capacity under static loading and the expected number of load cycles. So far there are no systematically investigations with substantial extent for cohesive soils.
The objective of the research project was to determine the influence of axial cyclic loading on the bearing capacity and the load-displacement performance also for cohesive soils.

For this purpose, static, cyclic and post-cyclic static field tests were performed on grouted micropiles in a mainly stiff clay with low to medium plasticity above groundwater. A total of five one-way cyclic load tests with up to 85,000 load cycles were conducted. The loading frequency was one cycle per minute and the average load level and the cyclic load amplitude were varied from test to test.

The test results show that in the investigated soil pile failure under cyclic one-way loading can be defined by accumulated pile displacements. In this research, failure was defined when the measured pile displacements exceeded 10 % of the pile shaft diameter. 100,000 load cycles and more are possible for average load levels up to 60 % of the bearing capacity of the pile (Ultimate Limit State) and load amplitudes up to 30% of the bearing capacity of the pile. An increase in displacement rates could not be detected in any of the cyclic load tests.

A reduced bearing capacity of post-cyclically loaded piles could not be determined. The bearing capacity was up to 20 % higher than that of not cyclically loaded piles. For load levels below the bearing capacity the post-cyclically loaded piles showed much lower creep rates at similar loads.

For the pile-soil system in this research project, therefore, there is no need to reduce the bearing capcity of the piles due to one-way cyclic loading. The required verifications in DIN 1054:2010 in the ultimate limit state and the serviceability limit state are sufficient.

Additional cyclic simple shear tests in the laboratory with undisturbed samples of the soil from the test site were conducted to simulate the performance of the soil near the pile shaft. They showed a comparable load-displacemnt behaviour: under one-way cylcic loading there is an accumulation of

displacements with time, but the displacement rates stay constant or decrease with time. To be able to deduce the pile displacements from simple shear tests further research is needed.
A comparison of the presented results and with the conclusions of other research projects shows that the influence of cyclic loading on the load-displacement behaviour or the bearing capacity of micropiles depends strongly on the type of loading (one-way, two-way) and the soil properties (plasticity, consistency, grade of saturation). Therefore a more precise differentiation within the cohesive soils is necessary. Further tests e.g. model tests on micropiles under cyclic loading in cohesive soils should be carried out varying the mentioned factors.