

Time Effects on Pile Capacity

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The main objective of the project was to establish how the axial tensile bearing capacity develops over time after a pile has been installed in the ground. The focus was on long term "ageing" effects that take place after possible excess pore pressures set up along the pile during installation are fully dissipated, but procedures for predicting the build-up of shaft friction in clays during the re-consolidation phase are also dealt with. To achieve the overall objective a comprehensive pile load testing program was undertaken at six different test sites and ground conditions: Two different sands deposits (a silty fine loose sand, and a medium fine to coarse, dense sand), and four different clay deposits (low and medium plastic normally consolidated clay, stiff over-consolidated low plastic glacial clay, and a stiff over-consolidated highly plastic clay).

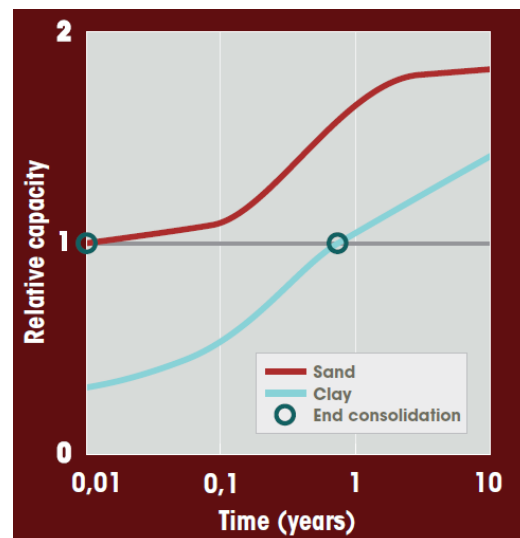
The key results from these pile tests are reported in a paper by Karlsrud et al. (2014) presented at the Offshore Technology Conference in Houston, Texas, USA, 5-8 May 2014.

Six tubular open-ended test piles were driven to a soil depth of about 20 m at each test site (only 5 at one site). The piles had a diameter of 400 and 500 mm and length of about 20 m. As originally planned for, all piles were loaded to failure in tension, which reduced any impact of tip resistance which made it easier to deduce ageing effects on the ultimate shaft friction without having to instrument the piles with strain gauges or load cells. The piles were loaded to failure at 5 different times, typically 1(2), 3(4), 6, 12 and 24 months after pile installation.

These systematic pile testing programs confirm that there are significant and positive gains in ultimate shaft friction with time for piles installed in both clay and sand deposits. For piles in clay this is a gain that comes in addition to the normal set-up due to dissipation of excess pore pressures generated during pile installation. For piles in sand it is a pure ageing effect as shown in the illustration below.

The observed ageing effect in clays suggests a linear increase in ultimate shaft friction with logarithm of time after the end of re-consolidation, but the rate of increase depends on the type of clay. The increase is clearly the largest for lean normally consolidated clays with low plasticity index (about 55 % gain from 3 months to 2 years), and smallest in highly plastic over-consolidated clays. The ageing effect also tends to reduce with increasing over-consolidation ratio of the clay. Some older data reviewed and included in the study suggest that the ultimate shaft friction may keep increasing for at least two decades after pile installation.

The gain in capacity with time for piles driven in sand deposits was found to be surprisingly large (increase by factor of about 2), and even larger than for piles installed in clay deposits. Unlike for piles in clay, the gain in ultimate shaft friction with time does not seem to follow a linear increase with logarithm of time, and tends to level off 1 to 2 years after pile installation.



The results show that there are distinct effects of repeated (staged) loading as well as of sustained loading on the gain in ultimate shaft friction with time. These effects are also very different for piles installed in sand as compared to in clay deposits, and needs to be accounted for when applying the results of this and earlier studies of time effects.

Given that described uncertainties in the interpreted gain in capacity with time is considered, the tentative procedures proposed by Karlsrud et al. (2014) for dealing with time or ageing effects should be applicable in design practice, irrespective of pile dimensions, and for piles loaded in compression as well as tension.