Changes in Soil During Pile Driving

53:139 Foundation Engineering
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Overview:

The process of constructing shallow foundations does not radically alter the properties of nearby soils. Neither does the process of constructing drilled shaft foundations significantly alter such in-situ soil properties as the relative density, or the lateral stress in the soil. Consequently, these soil properties measured in the SSE are representative of those that will exist following construction of the foundations. The same comments do not hold for soils in the vicinity of driven piles: The pile driving process can potentially generate large stresses and deformations in the nearby soil. The pre-construction soil properties are thus not necessarily representative of the postconstruction properties.This is an important source of uncertainty in pile foundation analysis and design.

A. Changes in Cohesive Soils

1. Soil within a few pile diameters can undergo large shear deformations. For many cohesive clay soils which tend to be highly sensitive to remolding, this leads to significant loss of strength in the short term.
2. Compression and Excess Porewater Pressure. (Figure 1) Driving of high displacement piles strongly compresses adjoining soils, and leads to a buildup of excess porewater pressure. This temporary buildup of excess porewater pressure (pwp), coupled with the sensitivity of the clay, causes the soil to lose a good fraction of its shear strength in the short term. This excess pwp dissipates over a time scale of a few weeks to a few months. As this occurs, the adjoining soil consolidates and increases its strength. The final strength can exceed the initial undisturbed shear strength of the soil. This behavior reflects the thixotropic nature of many clay soils. Thus, while piles may drive quite easily into saturated clay soils, after awhile the soil “sets up” or “freezes” in conjunction with the dissipation of the excess porewater pressure.
3. Loss of Side Contact Between Pile and Soil. (Figure 2) Piles wobble during the driving process. With stiff clays, this can lead to the formation of gaps between the pile and the soil. Soft, saturated clays that become disturbed will flow into these gaps; Stiffer, non-saturated clays generally will not flow into these gaps; These gaps have been observed to depths of 8–16 pile diameters; The possibility of these gaps means that skin friction is not reliable in this zone for stiff clays.

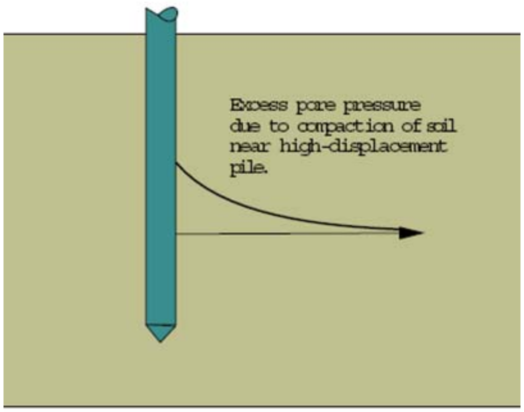


Figure 1: Buildup and distribution of excess porewater pressure near a high displacement pile.

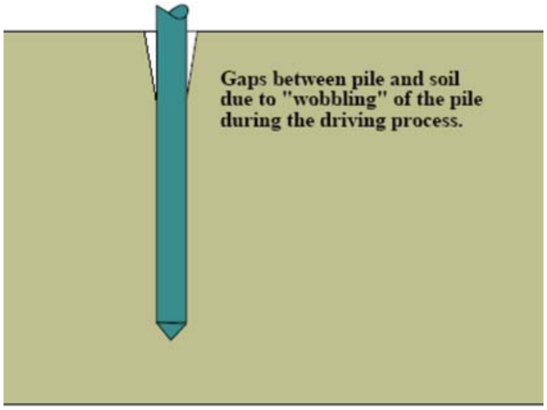


Figure 2: Lateral gap between pile and stiff cohesive soils due to pile wobble during driving.

B. Pile-Driving Induced Changes in Cohesionless Soils

Since excess pore-water pressure dissipates very rapidly in saturated cohesionless soils, the soil regains its strength very rapidly. If the cohesionless soil is dry, then there will be no pore pressure effects during the pile driving process, and thus no temporary loss or reduction of strength.

During driving of high-displacement piles, adjacent soils will experience high compressive stresses, causing a buildup of large lateral effective stresses. This effect is most pronounced when driving high displacement piles into soils with high relative density (Figure 3). Such soils experience shearing as the pile is driven in, and they tend to dilate (expand) generating very high lateral contact stresses between the pile and the soil. With time, these stresses may relax at least partially due to the viscoelastic nature of soils. In the short term, it can thus be very difficult to drive high displacement piles into dense cohesionless soils. Once they are driven in though, the skin friction capacity of such piles tends to be quite high, due to the high lateral effective stresses between the soil and the pile.

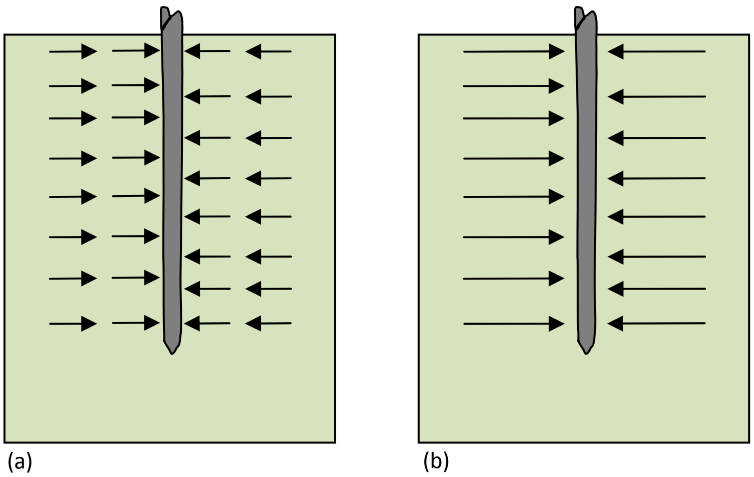
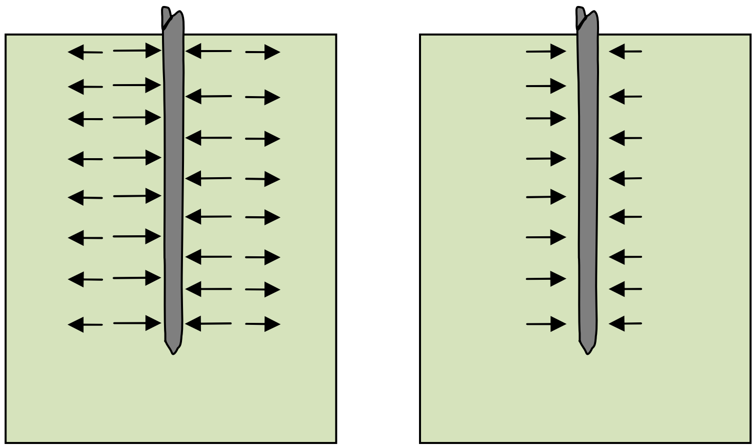


Figure 3. (a) High displacement pile driven into dense cohesionless soil. Lateral contact stresses σ'_h between pile and soil are high due to additive effects of: (1) displacement of the pile volume; and (2) dilatation (expansion) of the dense soil as it is sheared. (b) Resulting lateral effective stresses are large.

When piles are driven into loose cohesionless soils, the soil adjacent to the pile tends to densify as it is sheared. As a consequence, it can be relatively easy to drive high displacement piles into loose cohesionless soil deposits. Furthermore, the skin friction capacity of such piles will be less than that in dense soils due to the smaller lateral effective contact stresses between the pile and soil (Figure 4).



(a) (b)

Figure 4. (a) High displacement pile driven into loose cohesionless soil. Lateral contact stresses σ'_h between pile and soil are lower due to counteracting effects of: (1) displacement of the pile volume; and (2) densification of the dense soil as it is sheared. (b) Resulting lateral effective stresses are smaller.