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Shear behavior of the sand-concrete interface under cyclic thermal cycles

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Energy piles - foundation elements also used as heat exchangers - are subjected to daily and seasonal heating and cooling cycles, which might result in the modification of thermo-mechanical behavior of the soil-pile interface. In order to evaluate the effect of the pile's geothermal activation on a sand-concrete interface, at laboratory scale, a series of direct shear tests were performed using a device adapted for thermomechanical loading. The constant normal load (CNL) direct shear tests were carried out for three different thermal loading scenarios, i.e., at a constant temperature of 13°C, and for two different cooling-heating (8-18°C) cycles. The volumetric deformation after 10 thermal cycles is evaluated, and the shear results are compared.

A lot of studies [1, 2, 3, 4, 5, 6, 7, 8] have been performed to investigate the thermal effects on the shear behavior of soil-structure interface through direct shear tests. However, in previous studies all the thermal cycles were performed before the shearing phase. Hence, the effect of temperature cycles on the sand-concrete interface after the shear strength has already been mobilized (i.e., interface shear test) has not been well investigated so far. In fact, in real exploitation conditions, the thermal loading is usually added after a part of the mechanical loading or deformation occurred at the soil-pile interface, given the fact that the geothermal exploitation starts only once the building is in operation. To better understand the effects of thermal cycles on the shear properties of sand-concrete energy piles interface after a prior shear phase, a series of interface direct shear tests were performed in laboratory: (1) Reference Test (RT), shearing under constant temperature of 13°C (undisturbed soil temperature below 5 m in the Parisian region, France); (2) Cyclic Test 1 (CT-1), displacement controlled shearing under constant temperature (13°C), 10 thermal cycles (8 to 18°C), finally displacement-controlled shearing until the constant volume state was generated; (3) Cyclic Test 2 (CT-2), shearing to 1/2 of the residual shear strength, 10 thermal cycles (8 to 18°C), finally displacement-controlled shearing until the constant volume state was generated (CT-2 test). The monotonic displacement-controlled direct shear tests were conducted under constant normal stresses equal to 50 kPa, 100kPa and 150kPa that correspond to the typical normal effective stresses acting on the soil-pile interface at different depths.

Figure 1 presents the volumetric strain (ε_v) during the thermal cycles of CT-1 and CT-2. The sand samples are characterized by a contractive behavior during each heating phase and followed by an expansive behavior at the high temperature of 18°C. The samples continue to expand in the next cooling phase, then they start to contract when the low temperature of 8°C is constant. The volumetric strain changes are attributed to the thermal-induced particle rearrangement during the heating-cooling cycles. After the 10 thermal cycles, the sand samples show an overall contractive response. The thermal cycles induce more vertical strain on the samples of CT-2 than CT-1 (see Figure 1). The possible reason is that shearing to 1/2 residual shear strength develops more unstable particle rearrangement in CT-2 samples than shearing to the residual shear strength in CT-1 samples.

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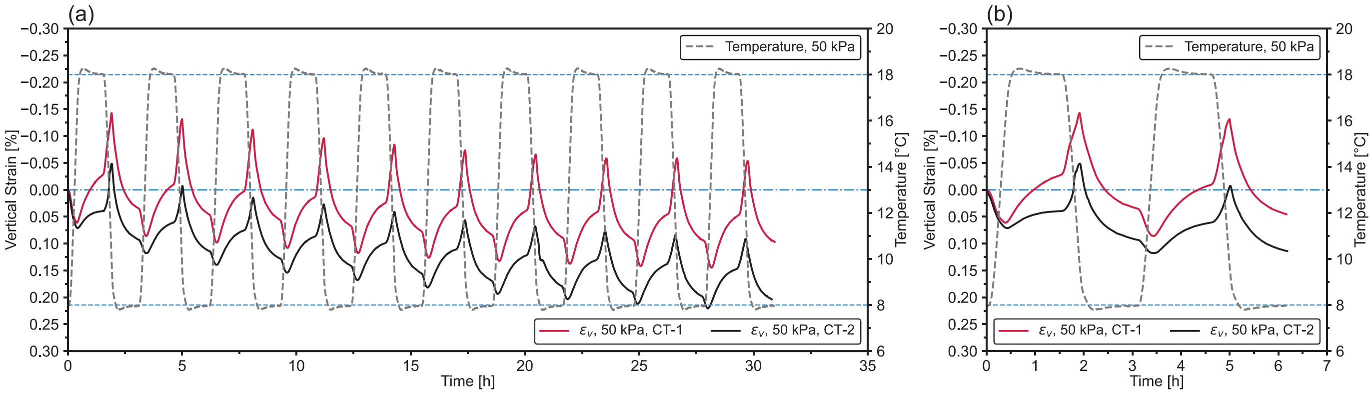

Figure 1: Vertical strain as a function of time and temperature during (a) the 10 and (b) the first two cyclic thermal cycles in CT-1 and CT-2 under the normal stress of 50 kPa.

The peak and residual interface friction angles of CT-1 and CT-2 after the 10 cyclic thermal cycles are compared with RT in Table 1. The peak interface friction angle of CT-1 is 28.9°, 0.6° lower than the one of RT (29.5°). Whereas a higher peak interface friction angle is mobilized in CT-2 (31.7°). CT-1 is characterized with a residual interface friction angle of 27.9°, which is 0.5° lower than the 28.4° of RT. However, the difference of residual interface friction angles between CT-2 (28.5°) and RT (28.4°) is only 0.1°. To conclude, the effect of the 10 cyclic thermal cycles on the sand-concrete interface is quite limited, it slightly decreases the peak as well as residual interface friction angles of CT-1 and increases these of CT-2.

Table 2: Comparison of the peak and residual interface friction angles of RT, CT-1, and CT-2.

	RT	CT-1	CT-2
Peak interface friction angle, δ_p (°)	29.5	28.9	31.7
Residual interface friction angle, δ_{cv} (°)	28.4	27.9	28.5

Contributor statement

Kexin Yin: Conceptualization, Methodology, Investigation, Data curation, Formal analysis, Writing - original draft, Visualization. Roxana Vasilescu: Conceptualization, Methodology, Resources, Formal analysis, Validation, Writing - review & editing.

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