Numerical Simulation of the Behaviour of Thermo-active Piles Using a t-z Methodology

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Introduction

The purpose of this paper is to compare the t-z methodology with the descriptive framework in the analysis of the behaviour of thermal-active piles, and to discuss the behaviour of thermo-active piles under the simulation of the t-z methodology. The framework simplifies the mechanisms for the thermal-active pile, however the descriptive framework only can be applied to analyse simple cases. A t-z methodology can be used to stimulate and analyse more complicated soil conditions. This paper will also discuss the results of various soil conditions, including the conclusions given by the descriptive framework and the site-test at Lambeth College. Besides, this paper will discuss the properties of soil, which affect the behaviour of thermo-active piles during thermal changes, and also the relations among pile stress, shaft shear stress and displacement.

1. DESCREPTIVE FRAMEWORK

In order to know the mechanisms of response affecting energy foundations, a descriptive framework is used to explain the contribution of the foundation material and various levels of end-restraint (Bourne-Webb et al. 2013). During heating and cooling cycles, the concrete of the energy pile expands and contracts, because concrete is an ideal medium for thermal conductivity and thermal storage capacity (Amatya et al. 2012). The expansion and contraction of pile alter the pile-soil interactions (Amatya et al. 2012). Therefore, when a pile is under heating and cooling, a complex behaviour is imposed upon the pile which is with different ground conditions and end-restraint (Bourne-Webb et al. 2013).

Thermal Response Without Soil Surrounding

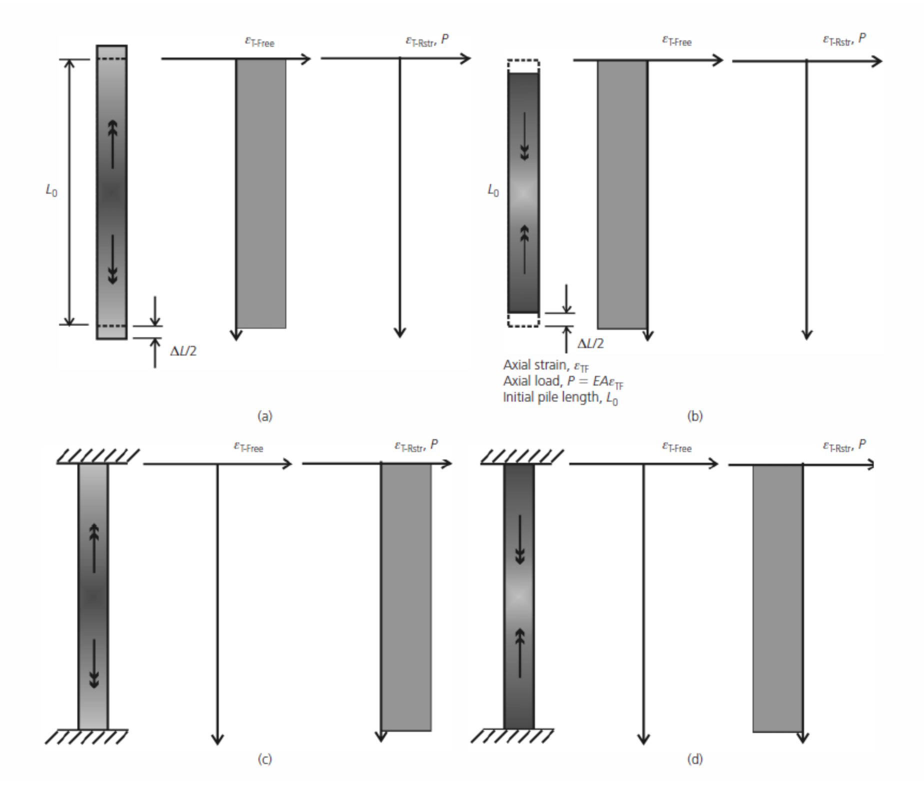


Figure 1. Thermal response of free and restrained bodies without soil surrounding: (a) heating, free body; (b) cooling, free body; (c) heating, restrained body; (d) cooling, restrained body (Bourne-Webb et al. 2013)

A pile expands as per its thermal characteristics according to the equation (1), where the free axial thermal strain without any restraint is ε_{T-Free}, the coefficient of the thermal expansion/ contraction of concrete is α_c and the net thermal change is ΔT (Amatya et al. 2012).

$$\varepsilon_{T-Free} = \alpha_c \, \Delta T \qquad (1)$$

Thermal Response With Soil Surrounding

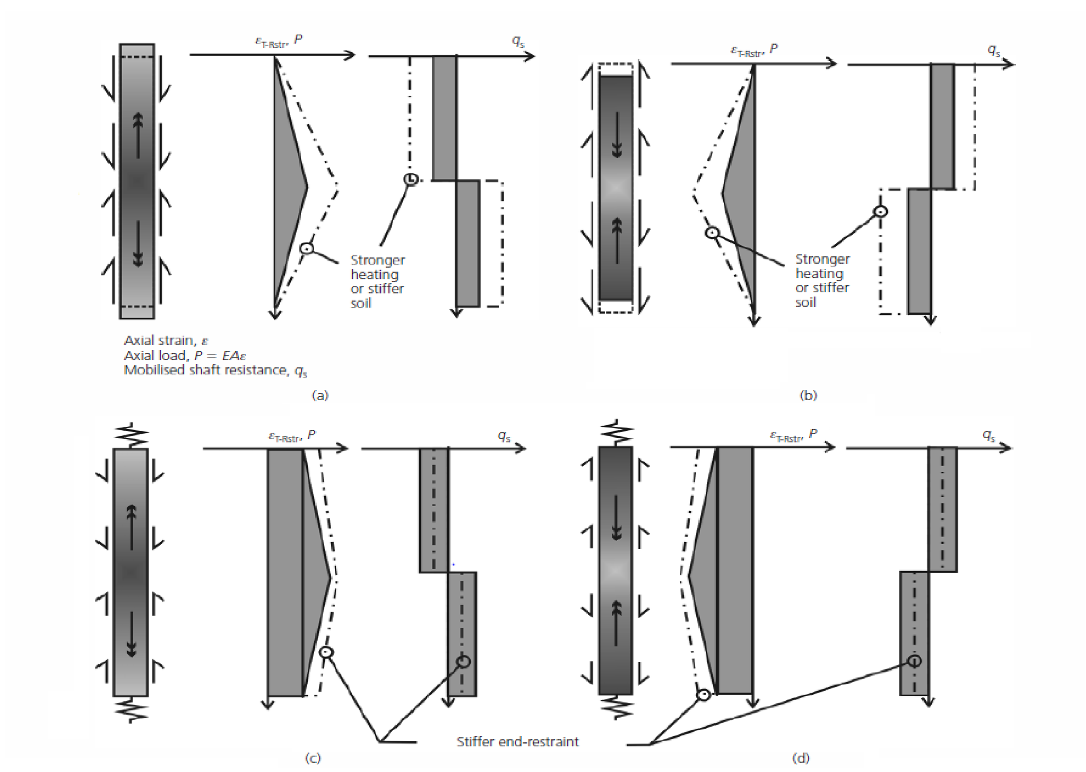


Figure 2 Thermal response of free-end and restrained bodies with soil surrounding: (a) heating, free body; (b) cooling, free body; (c) heating, restrained body; (d) cooling, restrained body (Bourne-Webb et al. 2013)

A pile is restricted by mobilisation of side restraint at the pile-soil interface and any end restraint either at the pile head or toe, then the measured strain change(ε_{T-Obs}) will be less than the strain change of pile without any restraint (ε_{T-Free}) (Amatya et al. 2012). Then the restrained axial strain (ε_{T-Rstr}) can be estimated as equation (2) (Amatya et al. 2012). The restrained strain(ε_{T-Rstr}) induces the thermal axial force(P_T) in the pile, which can be calculated as equation (3), where E is the Young's modulus of the pile material, and A is the cross-sectional area of the pile (Amatya et al. 2012).

$$\varepsilon_{T-Rstr} = \varepsilon_{T-Free} \; \varepsilon_{T-Obs} \qquad (2)$$

$$P_T = EA \, \varepsilon_{T-Rstr} = EA \, \varepsilon_{T-Free} \; \varepsilon_{T-Obs}) \qquad (3)$$

2. T-Z METHODOLOGY

Poulos (1989) proposed that these springs connecting pile elements each other can be treated as the stress-strain relationship, which is the relationship between axial load and pile stiffness. And the springs connecting elements to soils also can be treated as the stress-strain relationship, which is soil-pile interaction. Randolph et al.(2005) proposed the load-displacement relationship at each spring as the load transfer (t-z curve). All the springs connecting the pile elements to soil will produce tension and compression, except the spring at the base. And the force produced by these springs is the tangential force(t) in Figure 7. The change of the length of the spring is represented by z, which is the displacement of the pile element.

T-Z Model of a Pile

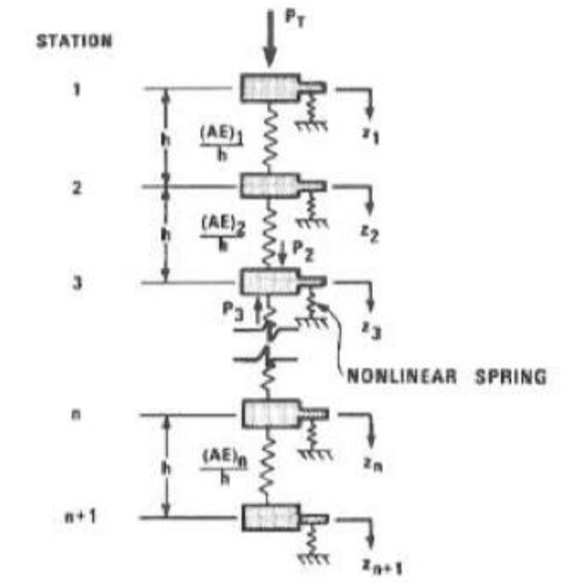


Figure 3. Load transfer model of a pile showing t-z soil springs and pile axial stiffness (Coyle & Reese, 1966)

T-Z Curve For Springs

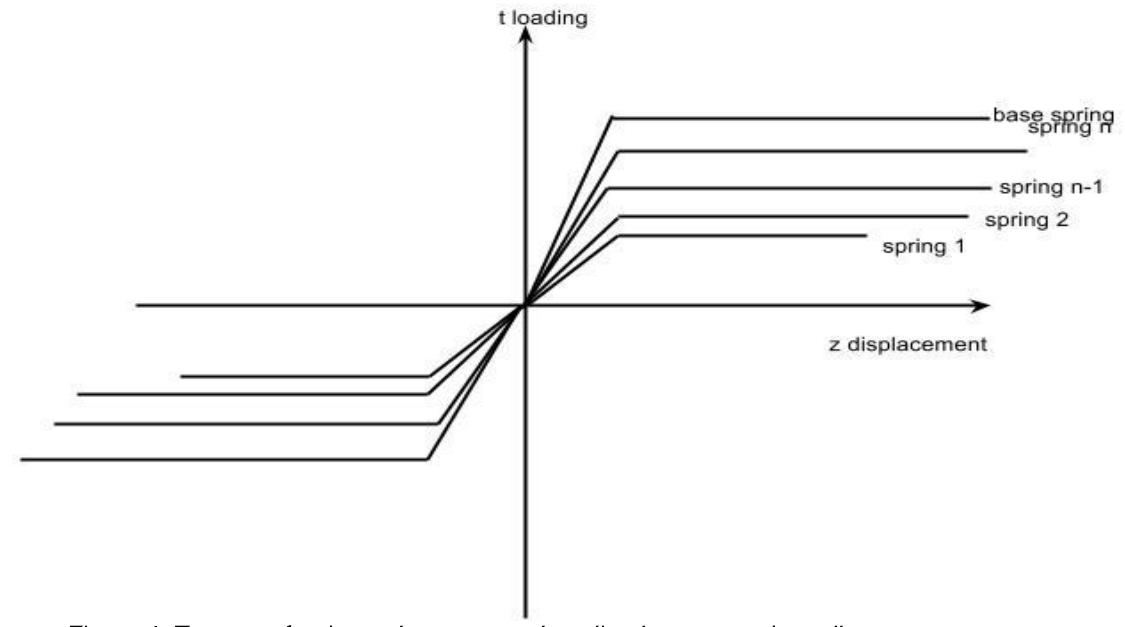
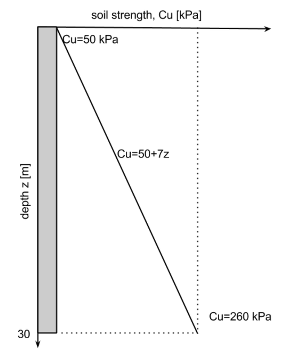
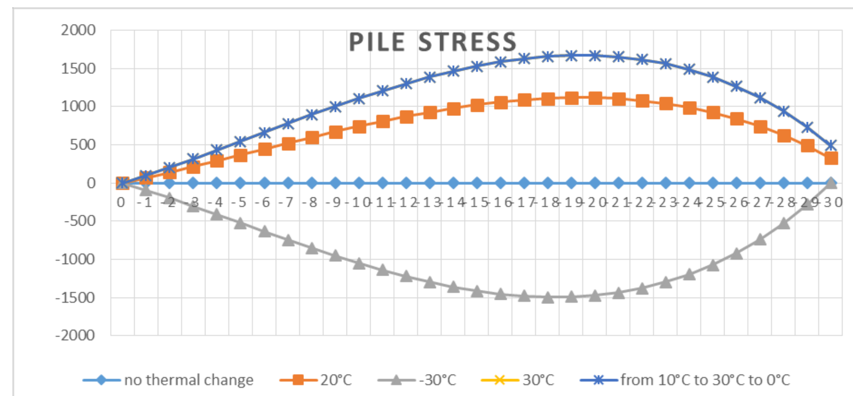


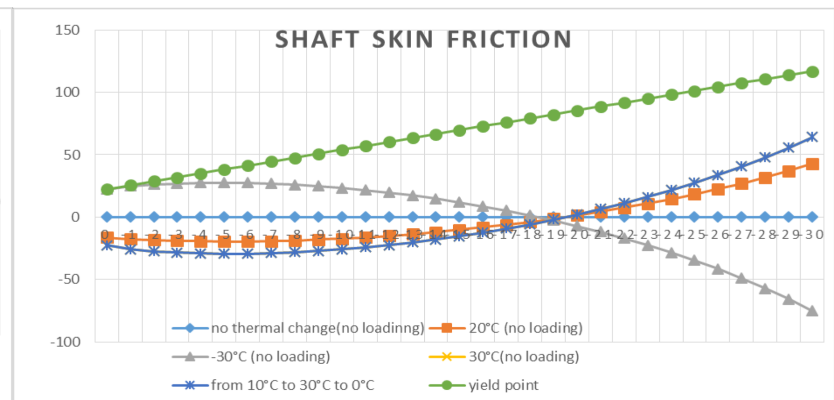
Figure 4. T-z curve for the springs connecting pile elements to the soil

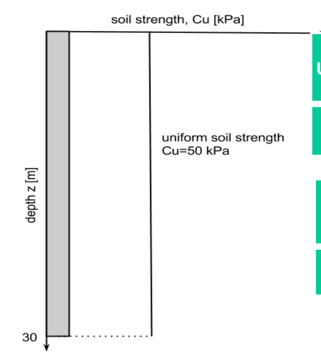
Oasys Pile is used to simulate the piles with various soil conditions under the effect of thermal change.



Undrained	Bulk unit weight	Top soil strength	Base soil strength	Top Young's modulus	Gradient of Young's modulus
London Clay	20kN/m3	50kPa	260kPa	22500kPa	3150kPa/m

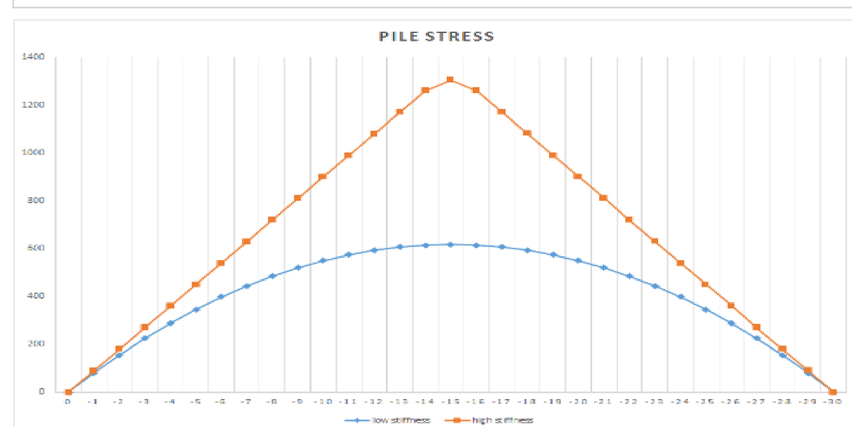


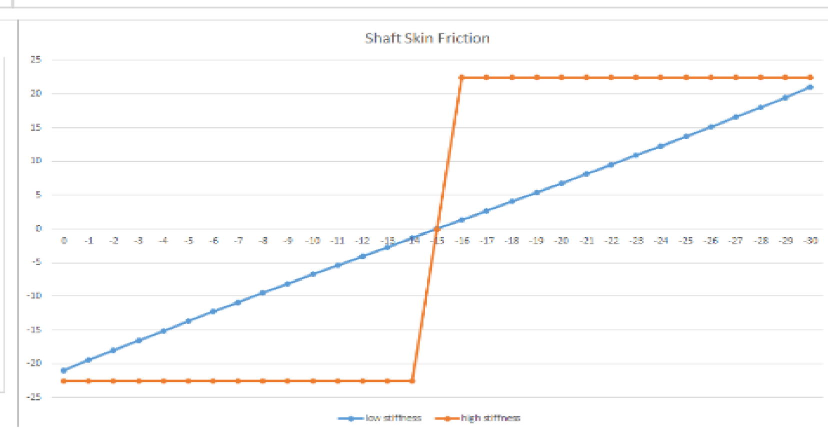




Undrained	Bulk unit weight	Top soil strength	Base soil strength (Cu)	Young's modulus (Eu)	Eu/Cu	Base Young's modulus
London Clay	$20kN/m3$	$50kPa$	$50kPa$	$2.25 \times 10^6 kPa$	45000	$1\ kPa$

Undrained	Bulk unit weight	Top soil strength	Base soil strength(Cu)	Young's modulus (Eu)	Eu/Cu	Base Young's modulus
London Clay	$20kN/m3$	$50kPa$	$50kPa$	$22500kPa$	450	$1\ kPa$





3. CONCLUSION

The main factors that affect the behaviour of thermal-active pile:

-Soil strength(C)

-Soil Stiffness(E)

-Soil at the base

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