Calibrating a T-bar factor for Calcareous Silt Subjected to Simple Shear

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ABSTRACT

Field tests suggest that the T-bar factor may vary over a large range for calcareous soils. As the T-bar penetrates very deep into soft soil, a full flow-round mechanism is formed around the T-bar. Examining the stress states around this mechanism suggests that soil elements are subjected to a varying stress state, and the element behaviour represents a combination of triaxial compression, simple shear, and triaxial extension conditions. This paper reports results of T-bar penetrometer tests performed at an elevated gravity of 150- \textit{g} (where \textit{g} is earth’s gravity) in a geotechnical centrifuge on a calcareous silty sediment collected from the North West Shelf of Australia. Once the centrifuge tests were completed, a tube sample was cored from the centrifuge strongbox. Two specimens were prepared from two reference depths, and undrained monotonic simple shear tests were carried out. The undrained shear strengths obtained from the simple shear tests were used to back analyse the T-bar bearing factor (\(N_{T-bar}\)). A mean T-bar factor of 9.92 was found for the calcareous silt tested. A three-dimensional large deformation finite element analysis was conducted to find out the T-bar factor in an ideal soil, showing the potential for undertaking further parametric analyses using an appropriate constitutive model to develop a robust interpretation framework for T-bar test data.

KEY WORDS: Calcareous silt; centrifuge; numerical modelling; simple shear; shear strength; T-bar.

T-BAR PENETROMETER AND BEARING FACTOR

Full-flow penetrometers (such as the T-bar, ball) are increasingly practiced both in laboratory environments (e.g. Purwana et al., 2005; Hossain et al., 2011) as well as in field investigations offshore (Erbrich & Hefer, 2002; Erbrich, 2005) due to its ability in: (i) providing a continuous stress profile that can be directly interpreted to the corresponding soil strength profile; and (ii) eliminating the necessity of overburden pressure corrections needed for the cone penetrometer (Lu et al., 2004; Zhou & Randolph, 2009). The T-bar penetrometer was first implemented by Stewart & Randolph (1994), and identified as advantageous for investigating fine-grained sediments due to the large projection area ratio (5~10 times larger than the cone penetrometer) leading to high resolution of soft seabed resistance. T-bar penetrometer tests allow any stratigraphy variance to be captured through measurements of the load through an attached load cell located just above the T-bar (Fig 1a). Depending on the penetration speed of the T-bar both undrained and drained strength can be inferred from the measured load (Finnie & Randolph, 1994).

Accurate interpretation of the resistance profiles from T-bar tests is of great importance to the geotechnical community. The undrained shear strength (\(s_u\)) of fine-grained soils (clays and silts) is conveniently related to the nominal bearing pressure (\(q_{T-bar}\)) using Eq. 1

\[ q_{T-bar} = N_{T-bar} s_u \]

where the nominal bearing pressure is obtained dividing the measured load by the projected area of the T-bar (i.e. length times diameter). \(N_{T-bar}\) is the bearing factor that depends on soil type, strain rate, soil sensitivity and remoulding, and the T-bar surface roughness.

For a deeply penetrated T-bar in soft soils, a full flow-round mechanism is mobilised, and the soil elements along the failure surface experience a complex stress state (Fig. 1b). The element directly beneath the T-bar experiences a stress state similar to triaxial compression (TC), whereas element right above the T-bar near the crown experience a triaxial extension (TE) stress state. Elements midway through the failure mechanism and located on the periphery along the springline are subjected under simple shear (SS) (see Fig. 1b). Therefore, an appropriate bearing factor representing these three test conditions should be used in Eq. 1.

Randolph & Houlsby (1984) and Martin & Randolph (2006) have reported plasticity solutions of a laterally loaded pile in cohesive soil. Deep or limiting bearing factors were presented as 9.14~9.20 (roughness factor, \(\alpha = 0\)) to 11.94 (roughness factor, \(\alpha = 1.0\)) i.e. as function of pile surface roughness. For interpreting T-bar test data, these values are used. As the surface of the T-bar penetrometers is generally sand blasted, a roughness of \(\alpha = -0.4\) is commonly assumed, and hence, for T-bar deep penetration in clay, a limiting bearing factor of 10.5 is selected for interpreting undrained shear strength in both laboratory and field tests.

The development of large deformation finite element (LDFE) method