The ICP Method

1. ICP method for clay

Unit skin friction f_{si} is calculated as

$$f_{si} = 0.8\ \sigma'_{rc} \tan \delta_f$$
$$\sigma'_{rc} = K_c\ p'_o$$

where
$\sigma'_{rc} =$ radial effective stress after equalization
$\delta_f =$ interface friction angle from ring shear test

$$K_c = \left[2.2 + 0.016\ OCR - 0.87\ \Delta I_{vy}\right] OCR^{0.42} \left[max\left(\frac{h}{R^*}, 8\right)\right]^{-0.2}$$

$p'_o =$ effective overburden pressure
$OCR =$ yield stress ratio or apparent over-consolidation ratio
$\Delta I_{vy} = \log S_t$
$S_t =$ sensitivity of clay
$h =$ distance above pile tip
$R^* = (R_o^2 - R_i^2)^{0.5}$
$R_o =$ outer radius of pile
$R_i =$ inner radius of pile

Unplugged end bearing $q_b = q_c$ on the area of pile annulus. q_c is CPT cone resistance at pile tip.

2. ICP method for sand

unit skin friction f_{si} is

compression: $f_{si} = (\sigma'_{rc} + \Delta\sigma'_{rd}) \tan \delta_{cv}$
tension: $f_{si} = \mathrm{a}\ (0.8\ \sigma'_{rc} + \Delta\sigma'_{rd}) \tan \delta_{cv}$

$$\sigma'_{rc} = 0.029\ q_c \left(\frac{p'_o}{p_a}\right)^{0.13} \left[max\left(\frac{h}{R^*}\right), 8\right]^{-0.38}$$

$$\Delta\sigma'_{rd} = 2G\frac{\Delta r}{R_o}$$

where
$\sigma'_{rc} =$ radial effective stress after equalization
$\Delta\sigma'_{rd} =$ increase in radial stress due to loading
$\delta_{cv} =$ constant volume interface friction angle
$\mathrm{a} = 0.9$ for open-end pile
$q_c =$ cone resistance
$p'_o =$ effective overburden pressure
$p_a =$ atmospheric pressure
$h =$ distance above pile tip
$R^* = (R_o^2 - R_i^2)^{0.5}$
$R_o =$ outer radius of pile
$R_i =$ inner radius of pile
$G =$ shear modulus
$\Delta r =$ interface dilation

Unplugged end bearing q_b is

$$q_b = A_r\,\bar{q_c}$$
$$A_r = 1 - \left(\frac{D_i}{D_o}\right)^2$$

where
$A_r =$ area ratio
$\bar{q_c} =$ cone resistance averaged over $\pm$1.5D about pile tip
$D_i =$ inner diameter of pile
$D_o =$ outer diameter of pile