Calibration of a New Static Rock Penetrometer (SRP): FEM Approach

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Abstract
In-situ tests are becoming increasingly popular to identify soft rock stratum during construction. In this study, the effect of the strength of the geomaterial on the penetration resistance of a new rock penetrometer was investigated using the finite element method (FEM).

1. Introduction
In order to support higher loads and/or geological conditions, more and more drilled shafts are being socketed in rocks (Nam et al. 2002). During the construction of drilled shafts in soft rock, it is critical to identify the rock stratum during the drilling process so that the drilled shaft could be correctly socketed in the rock. The static rock penetrometer (SRP) is being developed at the University of Houston to identify soft rock stratum during construction.

2. Objective
The objective of this study was to determine the effect of the geomaterial properties (modulus and undrained shear strength) on the penetration resistance of a rock penetrometer using FEM, and to determine the calibration factor for the penetrometer to obtain the undrained shear strength of the geomaterial.

3. Working of the SRP
The penetrometer comprises of a spring and plunger. When the SRP plunger is pushed against the geomaterial, the spring is deflected and the ring is displaced. It is of interest to investigate the geomaterial properties that influence the deflection of the spring.

4. FEM model
A schematic of the FEM model of the penetrometer and geomaterial is given in Fig.1. The boundary for the FEM analysis was taken to be forty times the plunger diameter. The geomaterial was modeled as a linearly elastic-perfectly plastic material with a Mohr-Coulomb yield criterion. The parameters of the geomaterial are summarized in Table 1 below.

Table 1: Properties of Geomaterial investigated

Material Model/Yield Criterion	Condition	Saturated volumetric weight lbf/in^3	Young's Modulus (psi)	Poisson's ratio	Undrained shear strength, C_u (psi)	Friction angle	dilatancy
Mohr-Coulomb(linear-elastic perfectly plastic)	Undrained	0.075	5000-30000	0.2	50-250	0	0

The soil penetration was modeled by giving prescribed displacements to the top of the SRP and developing the unit end bearing capacity-displacement relationship for various geomaterial strengths.

5. Test Results
The ultimate unit end bearing capacity (q_{ult}) at the tip of the plunger is related to the ring deflection as follows:

$$q_{ult} A = k\delta_{\max} \qquad (1)$$

where k is the spring constant (load per unit deflection), A is the cross-sectional area of the plunger and δ_{max} is the maximum spring deflection.

Based on the FEM analysis (Fig.2) for near surface conditions ($\sigma_v = 0$, vertical in-situ stress) the linear relationship obtained between the ultimate unit bearing capacity (q_{ult}) of the geomaterial and the undrained shear strength ($C_u = q_{unc}/2$) of the geomaterial for different initial moduli (E) can be represented as follows:

$$q_{ult} = N_c\, q_u/2 = N_c C_u = 7.84 C_u \qquad (2)$$

The constant N_c was found to be 7.84 using FEM. It should be noted that the q_{ult} was found to be independent of modulus and dependent on the undrained shear strength, C_u.

Combining equations (1) and (2) results in the following relationship:

$$\delta_{\max} = \frac{AN_c}{k} q_{unc} \text{ or } C_u = \frac{k}{2AN_c}\delta_{\max} \qquad (3)$$

Hence the undrained shear strength of the geomaterial is directly related to the spring deflection.

Vipulanandan et al. (2005) obtained a correlation between the ultimate unit bearing capacity and unconfined compressive strength, q_{unc} from field data for uncemented clay shale in Texas, which was as follows:

$$q_{ult} = 4.04 q_{unc} = 8.08 C_u \qquad (4)$$

Hence the N_c was 8.08. The FEM N_c value deviates from the field N_c value by 3%.

6. Conclusions

The maximum spring deflection was influenced by the undrained shear strength of the geomaterial; it was not influenced by the modulus of the geomaterial. The FEM ultimate unit bearing capacity factor, N_c was close to the one obtained from field data.

7. Acknowledgements

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8. References

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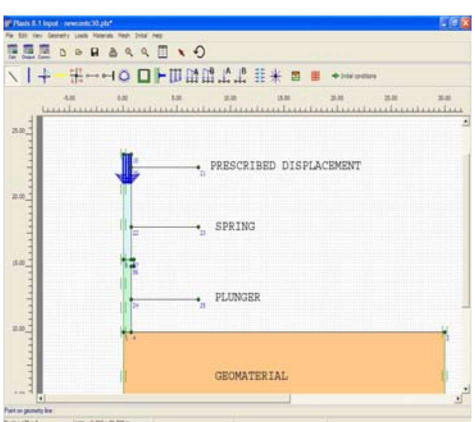

Fig.1: FEM Model of SRP

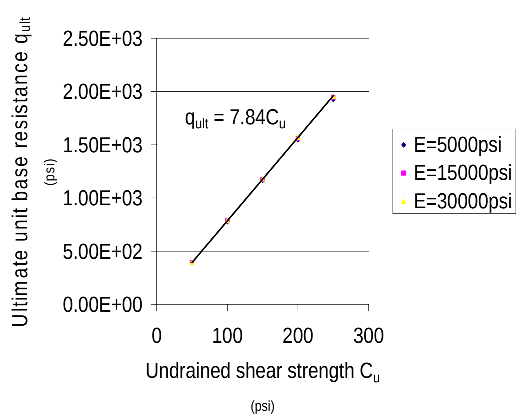

Fig.2: Relationship between q_{ult} and C_u