A NEW MODEL LINKING SOIL STRUCTURE TO STRENGTH

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The Motivation is

- The necessity of linking soil strength to measurable and calculable properties

...which is spurred by

- The lack of a satisfactory method of clay model preparation that would provide any desired strength-depth profile.
Previous work on clay strength suggests that

- Void ratio, stress history, and shearing rate are the parameters that control the peak strength of reconstituted clays.
- Clearly these parameters constitute measurable, calculable and controllable parameters.

Therefore

- A new testing model is necessary to observe the uncoupled effects of the parameters controlling clay strength.
Descending Gravity Test (DGT)

- is a new centrifugal testing method which combines in-situ tests with a new model preparation technique.
- provides clay models with constant OCR-varying void ratio profiles.
- allows the observation of the uncoupled effects of void ratio and OCR on shear strength.
The fundamental idea of DGT is that

- for a model that has reached normally consolidated state in the centrifuge, any decrease in the angular rotational velocity results in overconsolidation, which is a function of only previous maximum ($\omega_{\text{max}}$) and present angular rotational velocities ($\omega_u$).

\[
OCR = \frac{N_{\text{max}}}{N_u} = \frac{\omega_{\text{max}}^2}{\omega_u^2}
\]

where

\[
N = \frac{\omega^2 r}{g}
\]
Preparation of constant OCR-varying void ratio profiles by DGT
How to conduct tests during DGT?
Results obtained from DGT

- $e-S_u$ relationships are linear for constant OCR profiles.

- However, the zero intercept and slope of these relationships vary with OCR.

$$S_u = Te + R$$
Results obtained from DGT

\[ S_u = Te + R \]

\[ T = b_T OCR^{k_T} \]
\[ R = b_R OCR^{k_R} \]

T(OCR) and R(OCR) functions are found to be in the form of a power function.

\[ S_u = Te + R = \left( b_T OCR^{k_T} \right) + \left( b_R OCR^{k_R} \right) \]
Advantages of the defined $S_u(e, OCR)$ function

- Suitable for field conditions due to inherent anisotropy.

- Applicable to much wider range of soil conditions and it is not limited to the range of void ratios which it is calibrated for (including Hvorslev surface).

- Provides close peak undrained strength estimations using measurable and calculable soil properties.
Advantages of the defined $S_u(e, OCR)$ function

- Defines a material and rate dependent surface in the e-OCR-$S_u$, identified as a *Structural State Capacity Surface* (SSCS).
- Necessary parameters for SSCS can be obtained from a single DGT.
- SSCS is dependent on pre-shear soil properties, not soil properties at the time of failure.
Advantages of the defined $S_u(e, OCR)$ function

- SSCS defines a transition void ratio, which is possibly dependent on the grain shape and size.

- This transition void ratio identifies the Hvorslev surface.
Advantages of the defined $S_u(e, OCR)$ function

- SSCS incorporates the effects of both interlocking and friction on the undrained peak shear strength, unlike many other strength estimation methods that assume solely frictional behavior.

Depiction of SSCS on the $\sigma'_v - S_u$ plane.
$u_{ex}(e, OCR)$ function obtained by pore pressure measurements

- $u_{ex}(e, OCR)$ is similar to $S_u(e, OCR)$. This is expected since $u_{ex}$ generated as a result of CPT is a consequence of the deformation of the same structure.

- However, $u_{ex}(e, OCR)$ is in the form of an extended power function, unlike the power function behavior of $S_u(e, OCR)$.

$$u_{ex} = e \left( b_F (OCR + j_{FC})^{k_F} \right) + b_C (OCR + j_{FC})^{k_C}$$
CU MODEL

- The combination of $S_u(e, OCR)$ and $u_{ex}(e, OCR)$ relationships constitutes a structure based model. This model is called CU model.
- $S_u$ and $u_{ex}$ functions have the same variables; $e$ and OCR. Thus by using both of them it is possible to predict the void ratio and OCR profiles from the knowledge of $S_u$ and $u_{ex}$ profiles, which can be obtained by conducting piezocone penetration tests.
As a result, CU Model...

- links directly measurable and calculable properties to strength and testing generated excess pressures.
- is applicable to wide range of void ratio and OCR profiles and not limited to range which it is calibrated for.
- allows the calculation of void ratio and OCR from the knowledge of shear strength and testing generated excess pore pressures.
- parameters can be obtained by conducting a single DGT, which is a new centrifugal testing method that allows the observation of the uncoupled effects of void ratio and OCR on shear strength.