13- ChSoil Material Model – FLAC

This model is the ChSoil model that is presented in FLAC. The model is developed using the user-defined material model option in RS^2 and RS^3, and the users are provided with the dll file as an advanced example of this extension option. VIP users will have access to the C++ code of this model.

This model is a simplified version of the CySoil model. The model is designed to capture the deviatoric hardening behavior that is observed in soils that is associated with exhibition of decrease in the stiffness and irreversible deformations. Such a behavior was simulated by hyperbolic stress-strain in Duncan-Chang model. The short fallings of the Duncan-Change model are that, 1) constitutive behavior is applicable prior to the failure and my produce unrealistic behavior afterward, 2) the volumetric behavior such as dilation cannot be simulated, and 3) the behavior was independent of the Lode's angle; for example the stress ratio at failure would be the same in triaxial compression and extension tests. The ChSoil model is a good alternative to Duncan-Chang model and does not have its aforementioned limitations.

The model is built up on Mohr-Coulomd model and has a built in deviatoric hardening rule and tow options for plastic potential function. the elastic behavior is aldo nonlinear as the elastic modulus is dependent on the level of confinement. The yield surfaces and hardening characteristics of this model are illustrated in Figure 15.1.

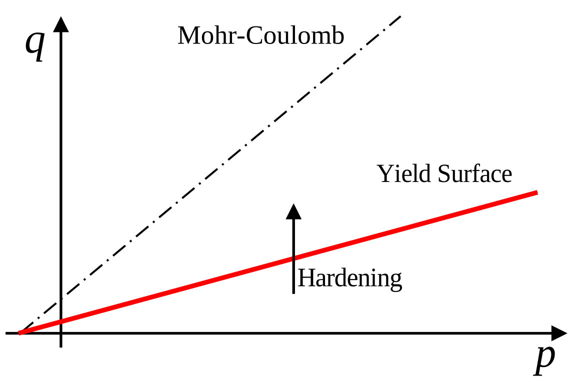

Figure 13.1- The yield surfaces of the CySoil Material Model;

The stress dependency of shear and bulk modulus in ChSoil model is formulated in separate but similar formulations

$$G_e = G_{ref}\left(\frac{p}{p_{ref}}\right)^n \quad , \quad K_e = K_{ref}\left(\frac{p}{p_{ref}}\right)^m \tag{13.1}$$

where G_{ref} and K_{ref} are the shear and bulk modulus numbers, respectively, p_{ref} is the reference pressure, and m and n, are the modulus exponents which control the stress dependency of the elastic modulus and they are within the range of $0.5 < m, n < 1.0$. The combination of the two equations in 15.1 should be such that the Poisson's ratio is in its admissible range.

The yield surface of ChSoil model is very similar to the yield surface of the Mohr-Coulomb model.

The equation for the deviatoric yield surface using the principal stresses (p, q, θ) invariants is given by

$$F_s = q - Mp - Nc = 0 \tag{13.2}$$

where

$$M = \frac{3 \sin \varphi_m}{\sqrt{3} \cos \theta - \sin \theta \sin \varphi_m} \quad , \quad N = \frac{3 \cos \varphi_m}{\sqrt{3} \cos \theta - \sin \theta \sin \varphi_m} \tag{13.3}$$

In above φ_m is the mobilized friction angle and c is the cohesion. The hardening for this yield surface is considered for the mobilized friction angle and it is attributed to plastic distortion, ε_q^p

$$\frac{d(\sin \varphi_m)}{d\left(\varepsilon_q^p\right)} = \frac{\sqrt{3}}{2} \frac{G_e}{p} \left(1 - \frac{\sin \varphi_m}{\sin \varphi_f} R_f\right)^2 \tag{13.4}$$

In above φ_f is the ultimate/failure friction angle, and R_f is the failure ratio and one of the material parameters (less than 1.0 with a default value 0.9.

To stablish an initial value for the mobilized fiction the model takes advantage of another parameter, φ_{nc}, normally consolidated friction angle. The initial state of stress is also checked against this initial friction angle, if the initial state is not on or inside the yield surface the value of initial friction angle will be calculated such that the initial state is on the yield surface.

There are two option for the flow rule for the deviatoric mechanism of this model. The flow rule is defined in terms of the relationship between the plastic volumetric strain and plastic deviatoric strain in a way that

$$\dot{\varepsilon}_v^p = \sin \psi_m \, \dot{\varepsilon}_q^p \tag{13.5}$$

where ψ_m is the mobilized dilation angle.

The first option is based on the stress-dilatancy theory by Rowe (1962). In this theory the mobilized dilation angle is calculated based on the mobilized friction angle φ_m and critical state friction angle

φ_{cv} . The essential concept behind the critical state friction angle is that while under shear the material will undergo compression if $\varphi_m > \varphi_{cv}$ and will dilate otherwise.

$$\sin\psi_m = \frac{\sin\varphi_m - \sin\varphi_{cv}}{1 - \sin\varphi_m \sin\varphi_{cv}} \tag{13.6}$$

$$\sin\varphi_{cv} = \frac{\sin\varphi - \sin\psi}{1 - \sin\varphi - \sin\psi} \tag{13.7}$$

In above ψ is the ultimate dilation angle.

The second option for the plastic potential uses a constant dilation angle, similar to that of the Mohr-Coulomb model where a dilation angle (ψ) is defined and controls the dilation tendency of the material, with a difference that it has accepts an input value for critical friction angle, φ_{cv}, and dilation only happens when the mobilized friction angle is larger than the critical friction angle.

$$\begin{aligned} \psi_m &= 0 \quad\quad if \quad \varphi_m < \varphi_{cv} \\ \psi_m &= \psi \quad\quad if \quad \varphi_m \geq \varphi_{cv} \end{aligned} \tag{13.8}$$

The model takes advantage of a tension cutoff as well. This mechanism is to incorporate the tensile strength of the material to this model. In this mechanism the minor principal stress is limited to the tensile strength of the material. The flow rule is associated and the mechanism has no hardening.

$$F_T = \sigma_1 - T = 0 \tag{13.9}$$

In above T is the tensile strength of the material.

References

FLAC, "User's manual" (2011).