

17- Soft Soil Model – PLAXIS

This model is the Soft Soil model as presented in PLAXIS manual. The model is developed using the user-defined material model option in RS² and RS³, 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.

The Soft Soil model is suitable for materials that exhibit high degrees of compressibility such as normally consolidated clays, clayey silts and peat. Based on this the dominant feature that should be considered in constitutive modelling of these materials is the volumetric hardening. Of course, a shear strength criterion also needed for these geomaterials and a Mohr Coulomb yield surface is considered for this purpose. The volumetric mechanism that captures the compressibility of the material is simulated by an elliptical cap that is very similar to the Modified Cam Clay model. The yield surfaces and hardening characteristics of this model are illustrated in Figure 17.1.

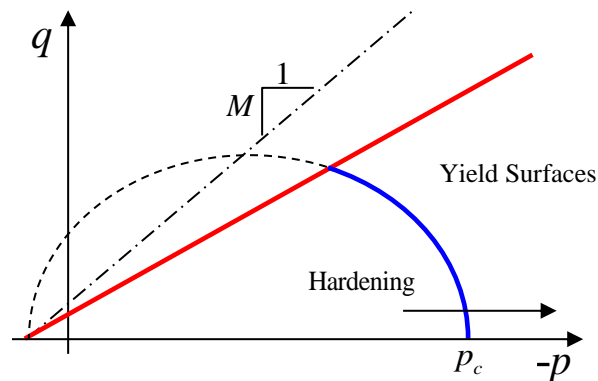


Figure 17.1 - The yield surfaces of the Soft Soil model; Mohr Coulomb yield surface (red) and elliptical cap (blue)

The formulations of these three mechanisms, definition of yield surfaces and their corresponding plastic potential and hardening law are presented below.

17.1- Virgin Consolidation Line and Swelling Line

Like the Cam Clay model this model assumes that when a soft soil sample is slowly compressed under isotropic stress conditions, and under perfectly drained conditions, the relationship between volumetric stress and logarithm of the mean stress is a straight line and when unloading the rebound is also a straight swelling line with a different slope (see Figure 8.2 and 17.2). Swelling lines are also called unloading-reloading lines.

The virgin compression line in Figure 17.2 is defined by the equation

$$\varepsilon_v - \varepsilon_v^0 = -\lambda^* \ln\left(\frac{p}{p^0}\right) \quad (17.1)$$

while the equation for a swelling line has the form

$$\varepsilon_v^e - \varepsilon_v^{e0} = -\kappa^* \ln\left(\frac{p}{p^0}\right) \quad (17.2)$$

Instead of specific volume (or void ratio) here the volumetric strain is considered in the formulation of the compression and swelling lines. And thus λ^* and κ^* are the modified compression and swelling indexes, and can be obtained from isotropic compression tests that include loading and unloading. The relationship between the modified compression and swelling indexes with the original ones and the well-known one dimensional compression and swelling C_c and C_r are

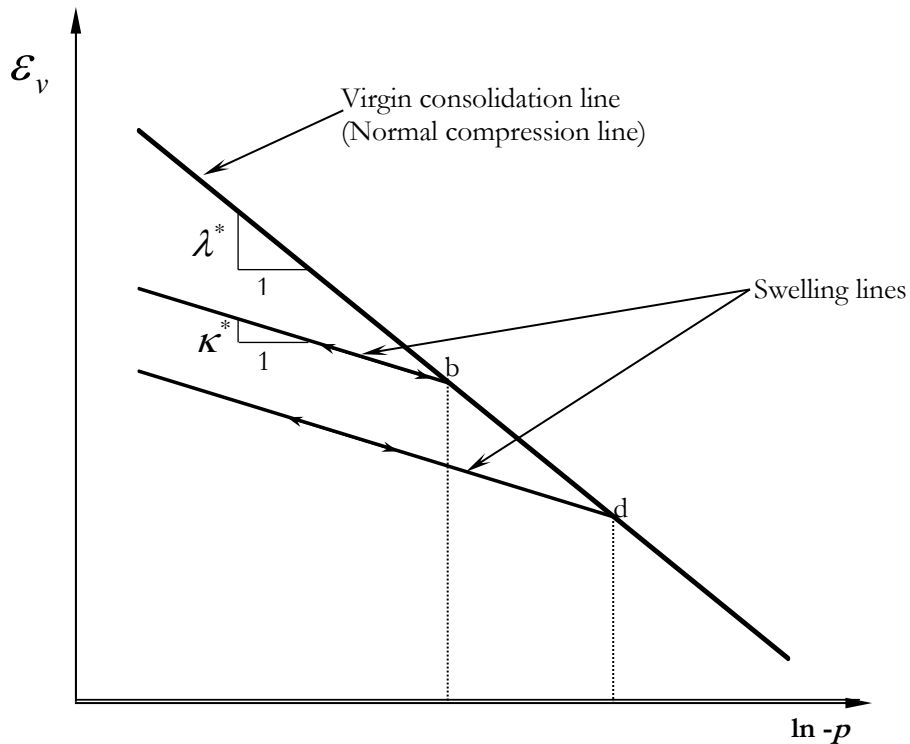


Figure 17.2. Typical behavior of soft soils in isotropic compression/swelling

$$\lambda^* = \frac{\lambda}{1+e} = \frac{C_c}{2.3(1+e)} \quad , \quad \kappa^* = \frac{\kappa}{1+e} \approx \frac{2C_r}{2.3(1+e)} \quad (17.3)$$

It is assumed that the soil behavior is elastic during unloading and reloading, and according equation (17.2) the bulk modulus can be calculated from equation (17.3). A minimum value for “ p ” is considered in the calculation of bulk modulus and also a constant Poisson’s ratio is considered for the elastic Hooke’s law.

$$K = \frac{p}{\kappa^*} = \frac{E}{3(1-2\nu)} \quad (17.3)$$

17.2- Volumetric Hardening Mechanism

The densification of the soft soils is captured by this mechanism in the Soft Soil model. The Yield surface of this mechanism is an elastic cap with its apex on the critical state line:

$$F_c = \frac{q^2}{M^2(p+c \cot(\varphi))} + p - p_c = 0 \quad (17.4)$$

where p_c is the location of the intersection of this yield surface with the p axis, and M is the slope of critical state line. This slope is different in triaxial compression and extension configurations like Mohr Coulomb model.

The hardening for these yield surfaces is considered for p_c and it is attributed to volumetric plastic strain generated only by the cap yield surface.

$$p_c = p_0 \exp\left(\frac{-\varepsilon_v^p}{\lambda^* - \kappa^*}\right) \quad (17.3)$$

The slope of the critical state line, M , is determined largely from the coefficient of lateral earth pressure K_0^{nc} evaluated from an oedometer test.

$$M = 3 \sqrt{\frac{(1-K_0^{nc})^2}{(1+2K_0^{nc})^2} + \frac{(1-K_0^{nc})(1-2\nu)\left(\frac{\lambda^*}{\kappa^*}-1\right)}{\frac{\lambda^*}{\kappa^*}(1+2K_0^{nc})(1-2\nu) - (1-K_0^{nc})(1+\nu)}}} \quad (17.4)$$

The flow rule is associated for this yield surface.

17.3- Deviatoric Mechanism – Shear Strength

The deviatoric mechanism in this model is to introduce the shear strength to the model and it is a Mohr-Coulomb yield surface that is defined by a friction angle (φ) and cohesion (c). The slope of the Mohr Coulomb yield surface is less than the critical state line. The two yield surfaces intersect the p axis at the minimum value of confinement equal to $c \cot(\varphi)$.

Since soft soils do not show a significant dilation while shearing, the dilation angle for this mechanism is usually set to zero ($\psi = 0$)

17.4- Examples

Figure 17.3 and 17.4 shows the numerical results of drained and undrained triaxial tests on a soft soil. A comparison is made between the results obtained by Soft Soil model in PLAXIS and simulation results of the Soft Soil model in Rocscience products. The model parameters are presented in Table 17.1.

λ^* and κ^*

Characteristics	Values
λ^*	0.1055
κ^*	0.01635
ν (Poisson's ratio)	0.15
K_0^{nc}	0.61
φ (degrees)	38
ψ (degrees)	0
c (kPa)	0
p_{\min} (kPa)	1
OCR	1

Table 17.1. Soft Soil model parameters

References

Plaxis, "User's manual of PLAXIS." (2014).

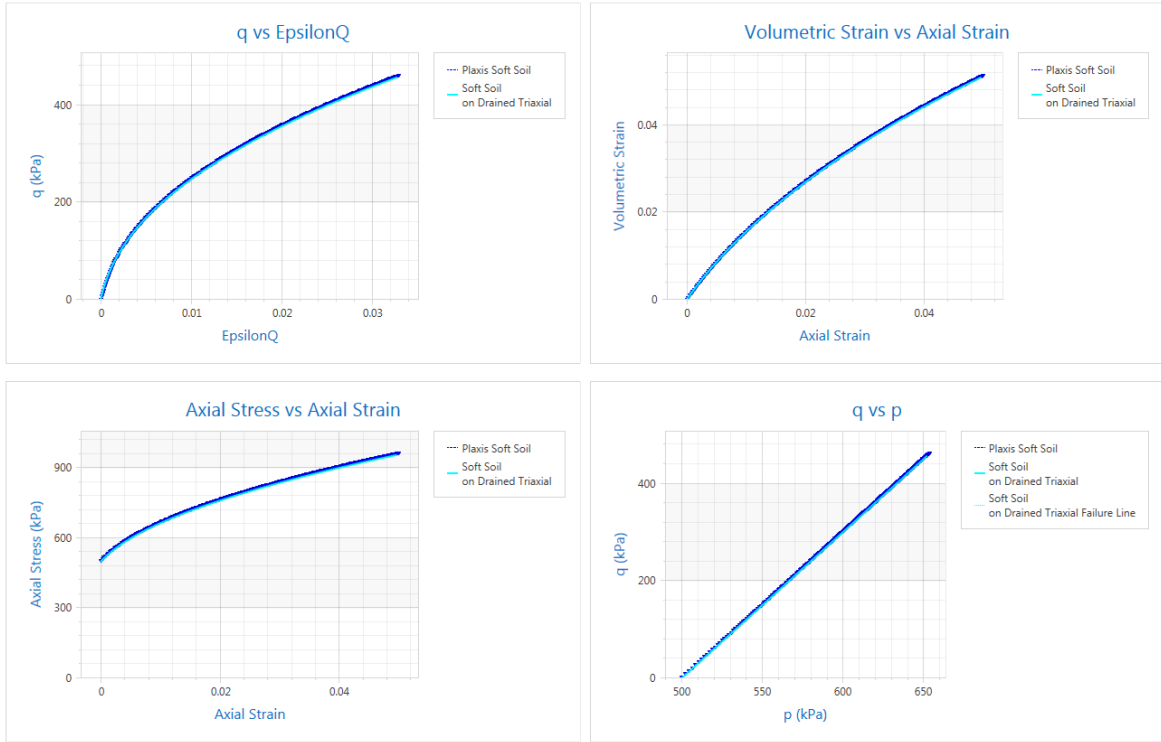


Figure 17.3. Stress paths of drained triaxial tests on a soft soil

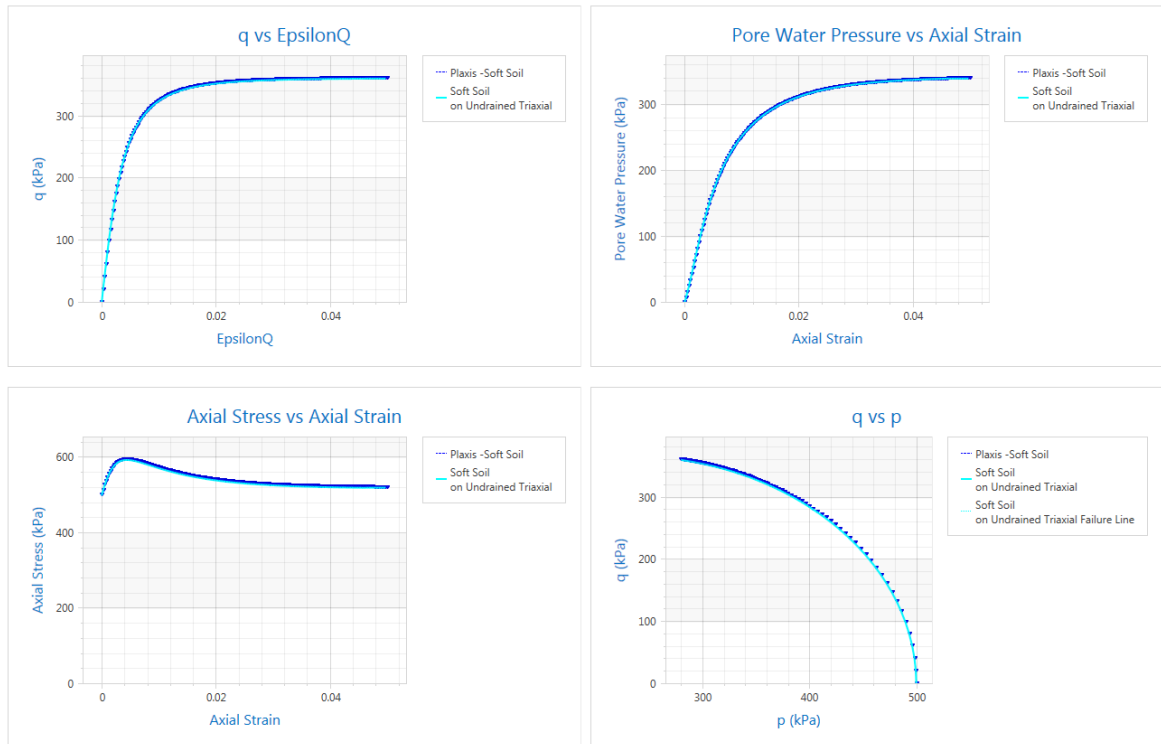


Figure 17.4. Stress paths of undrained triaxial tests on a soft soil