18- Soft Soil Creep Model – PLAXIS

This model is the Soft Soil Creep model as presented in PLAXIS manual. The model is developed using the user-defined material model option in RS^2 and RS^3.

The Soft Soil Creep model is suitable for materials that exhibit high degrees of compressibility and exhibit significant creep behavior (e.g. secondary consolidation in an oedometer test). The features that are considered in this model are stress-dependency of stiffness; distinction between primary loading and unloading-reloading, timedependent compression, memory of preconsolidation stress; shear strength following the Mohr-Coulomb (MC) failure criterion, creep yield surface adapted from the Modified Cam-Clay model with an associated flow rule.

The main assumption in consideration of creep behavior in this model is that the elastic strains are instantaneous and plastic strains are only viscous and will develop over time. The viscoplastic strains are in development throughout the entire time but the rate at which they are developed will depend on number of factors as presented in equation (18.1).

$$\dot{\varepsilon}_{ij} = \dot{\varepsilon}_{ij}^{e} + \dot{\varepsilon}_{ij}^{c} \tag{18.1}$$

The superscript e and c stand for elastic and creep respectively.

The formulations presented below use the compression positive convention as it is in the reference.

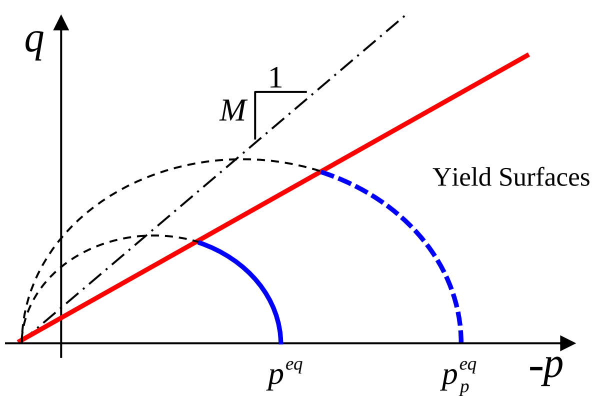

Figure 18.1 - The yield surfaces of the Soft Soil Creep model; Mohr Coulomb yield surface (red) and elliptical caps for calculations of viscoplastic strains (blue)

18.1- Creep Behavior and Calculation of Viscoplastic Strain

The creep volumetric strain, $\dot{\varepsilon}_v^c$, is calculated from the equation blew.

$$\dot{\varepsilon}_v^c = \frac{\mu^*}{\tau}\left(\frac{p^{eq}}{p_p^{eq}}\right)^{\frac{\lambda^*-\kappa^*}{\mu^*}} \tag{18.2}$$

In above λ^* and κ^* are the modified compression and swelling indexes, and can be obtained from isotropic compression tests that include loading and unloading, μ^* is the modified creep index, p^{eq} is a new stress measure that is calculated based on the current stress state in equation (18.3), p_p^{eq} is the generalized equivalent pre-consolidation pressure defined in equation (18.4), and τ is one day.

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

$$\lambda^* = \frac{\lambda}{1+e} = \frac{C_c}{2.3(1+e)} \quad , \quad \kappa^* = \frac{\kappa}{1+e} \approx \frac{2C_r}{2.3(1+e)} \tag{18.2}$$

$$p^{eq} = p + \frac{q^2}{M^2\left(p + c\cot\varphi\right)} \tag{18.3}$$

In above p and q are stress invariants calculated based on the current stress state and M is the slope of critical state line, c and φ are the cohesion and friction angle of the material used to define its shear strength with a Mohr-Coulomb criterion.

$$p_p^{eq} = p_{p0}^{eq}\exp\left(\frac{\varepsilon_v^c}{\lambda^*-\kappa^*}\right) \tag{188.3}$$

The subscript 0 in above denotes to initial condition when the time and creep volumetric strain are zero.

Figure 18.1 shows that the stress measure p^{eq} represents an ellipse in *p-q* plane. The ellipse follows the same shape and formulation as in Modified Cam Clay model with a lateral shift on the *p* axis. The generalized equivalent preconsolidation pressure is also shown in Figure 18.1. The magnitude of creep strain is negligible when p^{eq} is less than p_p^{eq}. The time dependent deformations will become more significant for cases when p^{eq} is greater than p_p^{eq}. In the latter case the rate of creep deformations will gradually decrease as the two values get closer to each other.

The plastic potential is assumed to be the same as in equation (18.3), thus the creap strain tensor can be calculated as:

$$\dot{\varepsilon}_{ij}^{c} = \left(\frac{\partial p^{eq}}{\partial p}\right)\frac{\mu^*}{\tau}\left(\frac{p^{eq}}{p_p^{eq}}\right)^{\frac{\lambda^*-\kappa^*}{\mu^*}}\left(\frac{\partial p^{eq}}{\partial \sigma_{ij}}\right) \tag{18.4}$$

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

$$M = 3\sqrt{\frac{(1-K_0^{nc})^2}{(1+2K_0^{nc})^2} + \frac{(1-K_0^{nc})(1-2\nu)\left(\frac{\lambda^*}{\kappa^*}-1\right)}{\frac{\lambda^*}{\kappa^*}(1+2K_0^{nc})(1-2\nu) - (1-K_0^{nc})(1+\nu)}} \tag{18.5}$$

The elastic behavior is similar to that in the Modified Cam Clay model assuming a constant Poisson's ratio, and a bulk modulus that is dependent on the confinement and the swelling index.

$$K = \frac{p}{\kappa^*} = \frac{E_{ur}}{3(1-2\nu_{ur})} \tag{17.3}$$

In above the subscript *ur* stands for unloading/reloading. A minimum value for " p " is considered in the calculation of bulk modulus.

18.2- 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 $c\cot(\varphi)$.

The moment the stress state reaches to the Mohr Coulomb yield surface instantaneous plastic strains will develop according to this mechanism and its plastic flow rule. Since soft soils do not show a significant dilation while shearing, the dilation angle for this mechanism is usually set to zero $(\psi = 0)$.

18.3- 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 Creep model in PLAXIS and simulation results of the Soft Soil model in Rocscience products. The model parameters are presented in Table 18.1. The applied time steps for the simulations are 1 minutes.

Characteristics	Values
λ^*	0.1055
κ^*	0.01635
μ^*	0.04
ν (Poisson’s ratio)	0.15
K_0^{nc}	0.61
φ (degrees)	32
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).

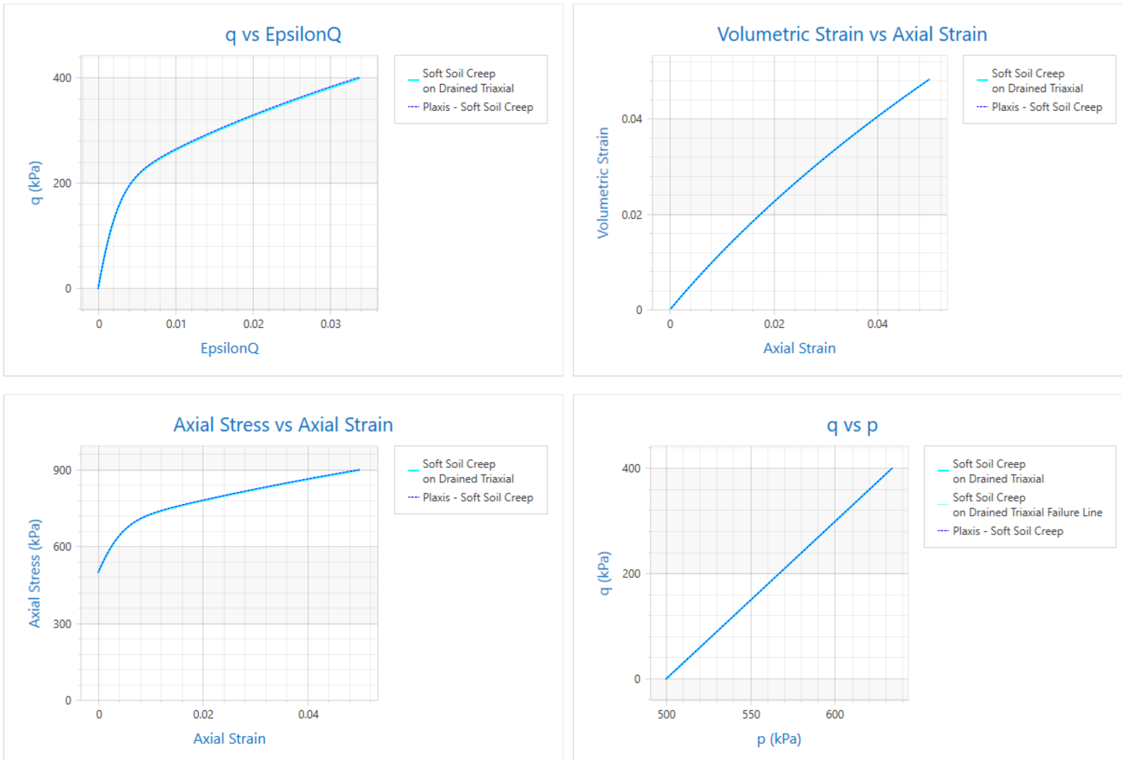

Figure 18.2. Stress paths of drained triaxial tests on a soft soil creep material (dt=1min)

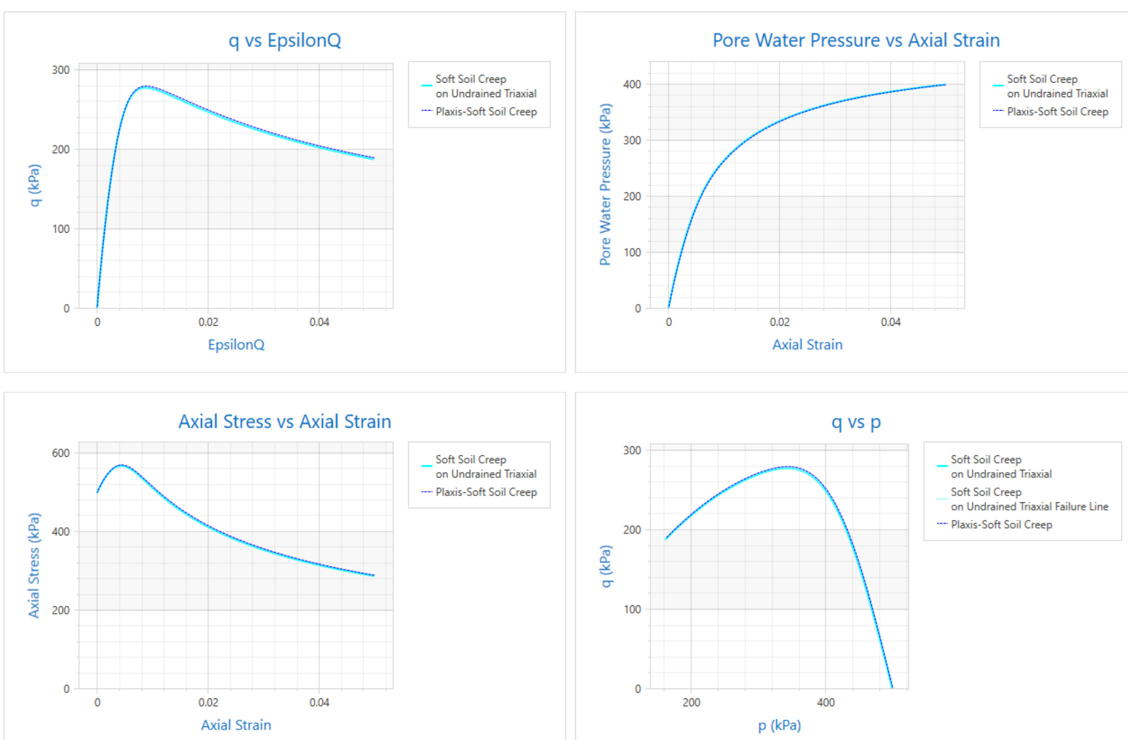

Figure 17.4. Stress paths of undrained triaxial tests on a soft soil creep material (dt=1min)