



PRACTICAL APPLICATION OF THE SOFT SOIL CREEP MODEL

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The Soft Soil Creep model distinguishes between primary loading and unloading/reloading behaviour and in this respect the model is similar to the Hardening Soil and Soft Soil models. In the last two models the distinction is made by means of a cap, i.e. a curved plane in stress space that defines the limit stress state between those two modes of loading. The position of this cap is initially determined by the preconsolidation stress. However, in the Soft Soil model the position of the cap is not only determined by the maximum stress state that has been reached in the past, as is the case in the other two models, but it is also a function of time.

In the Hardening Soil (HS) and Soft Soil (SS) models there is no time dependency in the model. The cap expands instantaneously if an increase in the load would cause the stress state to fall outside the current cap. In the Soft Soil Creep (SSC) model this shift of the cap needs time. If a higher load is applied, the cap will not follow immediately, but will take 1 day to adapt to the new stress state. This value of 1 day is an arbitrarily chosen value used in the model and can not be varied by the user.

Furthermore, when the cap reaches the applied stress state after one day, it will not stop expanding but continue to expand with a continuously decreasing expansion rate. Any change in the stress state will cause a change in the velocity with which the cap expands; an increase in stress, even when the stress remains below the cap, will cause an increased velocity of the cap expansion. Similarly, a decrease of stress will cause a decrease in the velocity of the cap expansion. The cap will, however, always keep expanding.

It is evident that time is essential for the behaviour of the cap; therefore Plaxis Calculations will give a warning if a project in which the SSC model is used contains phases with a zero time step. Please note that this is a warning that can be ignored in some cases. An example would be a calculation phase where the soil layer that is modelled with the SSC model is not activated yet.

As mentioned above the expansion velocity of the cap depends on time. This has consequences for the determination of the initial stresses as the history of the soil plays a major role here. Let's for example assume an embankment was constructed several months ago, consisting of soft soils which strongly exhibit creep behaviour. Presently we would like to continue construction on top of that embankment.

When we construct a model for this case and assume that the subsoil and the embankment are both drained this could be easily modelled using time independent soil behaviour. In that case the embankment could be activated in the first calculation phase to model the present day situation; whether the embankment was built last week or last year is not important then.

However, when the Soft Soil Creep model is used the time that has elapsed since the construction of the embankment is important for the construction on top of the embankment. It will influence not only the long term displacements but also the short term displacements. If the embankment had been built long ago, it would have had more time to creep. This would mean that the cap would have expanded more. Hence, when loaded the embankment would show a stiffer (reloading) behaviour and less primary loading than if it were built only a week ago. An older embankment will show less short term settlements. The creep velocity will always increase due to the construction on top, but a more recently constructed embankment will always creep faster than an embankment that has been constructed long ago. As a result the long term settlements for a more recently constructed embankment will also be larger than in the case of an older embankment.

This example shows that the construction history is far more important when using the SSC model than it would be when using a time independent model. Of course the entire construction history can be modelled also, including the time between the actual construction of the embankment and the present day. There are many cases, however, where the in situ history is not so clear. This is commonly the case when dealing with soft soil layers that have been undisturbed for centuries, but these soft layers will greatly influence the deformations of anything built on top.

In order to properly model the creep behaviour two main parameters are needed for the initial situation at $t=0$. These are the location of the cap and its expansion velocity. These parameters cannot be entered directly by the user, but must be specified by means of the parameters μ^* (modified creep index) and the OCR. The change of the creep rate in time is defined by the combination of parameters λ^* , κ^* and μ^* where the modified creep index specifies the creep rate after 1 day. The creep rate for a specific soil is derived from these three parameters (see formula 6.23 in the Plaxis Material Models manual) so that the volume change due to creep over a period Δt equals

$$\Delta \mathcal{E}_v^c = \mu^* \ln \left(1 + \frac{\Delta t}{1 \text{ day}} \left(\frac{p_{eq}}{p_{c0}} \right)^{\frac{\lambda^* - \kappa^*}{\mu^*}} \right)$$

This defines the time-dependent creep behaviour, but does not yet define at what creep rate the Plaxis calculation starts. The latter is defined by the OCR. In the SS and HS model the OCR is simply the ratio of the maximum stress state ever reached in the past (the preconsolidation stress) and the current stress state. The same holds for the SSC model, but in this case the position of the cap is also time dependent. So the correct value of the OCR should also take into account the time elapsed since the soil was formed and started creeping.

By default Plaxis assigns an OCR=1 to all clusters. In the SSC model this would mean that there has been creep for only one day. As said before, when the stress is increased beyond the cap it will take 1 day for the cap to expand to the new stress state, that means to the situation where OCR equals 1. This also means that the Plaxis defaults are only suited for a newly applied material which will exhibit large creep deformations. This is generally not the case for creep sensitive layers in the subsoil.

Those layers should initially be assigned a proper OCR that represents the history of that layer. There are basically two ways to do this. The first possibility is to assign an OCR in Initial Conditions by either double-clicking on a cluster or specifying the OCR in the table of K_0 -values before starting the initial stress procedure (K_0 -procedure). The OCR can be obtained from proper laboratory tests but these may not always be available. Alternatively it is possible to estimate the OCR for soils where the last load step was primary (virgin) loading and the overburden has been constant ever since. In this case the OCR can be estimated using:

$$OCR \cong e^{\frac{\mu^*}{\lambda^* - \kappa^*} \ln(\Delta t)}$$

In this formula Δt is the time in days that has elapsed since the last primary loading step. Typically this is the time since the material was deposited, and in case of the OCR for an existing clay or peat layer it could even be a time in days equal to hundreds of years.

The second possibility to assign a correct OCR value in Plaxis is to leave the OCR equal to 1 in the initial conditions and start the calculation with a plastic nil step. For this phase set the time interval equal to Δt . Plaxis will now calculate the stress state due the creep over that period, which results in a certain OCR. In the second phase of the calculation the settlements due to the simulation of the creep history must be discarded using the “reset displacements to zero” option in Plaxis Calculations.

Generally, if Δt is large the exact value becomes less important, as the OCR depends on natural logarithm of time. It makes a large difference whether soil has been in place for 10 days or 1 year, but there will be relatively little additional creep between 100 years or 200 years.

When generating the initial stresses using the K_0 -procedure, the influence of the OCR warrants some extra attention. The initial vertical preconsolidation stress at a certain depth is calculated, as might be expected, from the effective weight of the soil on top multiplied by the OCR value that has been entered ($\sigma_c = \text{OCR} \cdot \sigma'_y$). When a plot of the OCR values obtained in this way is inspected, it can be noticed that the reported OCR values differ slightly from the enter value. The reason for this is that the OCR value Plaxis Output reports is calculated using the stress measure p^{eq} , defined as

$$p^{eq} = p' + \frac{q^2}{M^2(p' + c \cot(\phi))}$$

This stress measure is used internally by Plaxis to define OCR from $p_p = \text{OCR} \cdot p^{eq}$. The reason for this is that the regular definition of OCR ($\sigma_c = \text{OCR} \cdot \sigma'_y$) is not always meaningful in complex 3D loading situations. And although it would be preferable to report OCRs using the same definition as used in the initial conditions, unfortunately it is not possible to derive Cartesian stresses from p^{eq} in case the cohesion is nonzero.

In order to illustrate this a simple example is given. Define in Plaxis V8 a square of 1x1m with standard boundary conditions and a distributed load on top.

Define a material data set using the Soft Soil Creep model and the material type set to drained. Other material parameters are given in table 1. Normally one would use undrained material behaviour but to more clearly illustrate creep only drained behaviour is selected here.

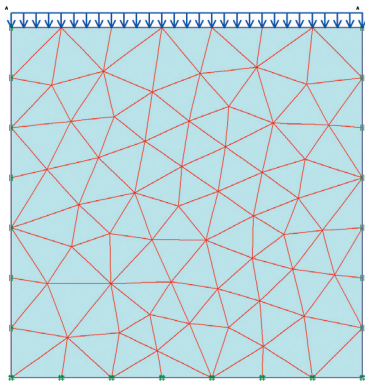


Figure 1: Geometry used in this example.

| Parameter | Name | Value | Unit |
|--|-------------------------|-----------------|-------------------|
| Material model | Model | Soft Soil Creep | - |
| Type of material behaviour | Type | Drained | - |
| Unit weight of soil above phreatic level | γ_{unsat} | 17.0 | kN/m ³ |
| Unit weight of soil below phreatic level | γ_{sat} | 17.0 | kN/m ³ |
| Modified compression modulus | λ^* | 0.025 | - |
| Modified swelling modulus | κ^* | 0.010 | - |
| Modified creep modulus | μ^* | 0.001 | - |
| Cohesion (constant) | c_{ref} | 1.0 | kN/m ² |
| Friction angle | ϕ | 28.0 | ° |
| Dilatancy angle | ψ | 0.0 | ° |

Table 1: Material parameters

For this case the sample is assumed dry and for initial stresses generation the default values for K_0 and OCR are used. The calculation consists of 5 phases:

1. A load of -100 kPa is applied at the top with time interval zero.
2. A staged construction phase with a time interval of 100 days. Use the “reset displacements to zero” option.
3. Starting from the initial phase once more add a staged construction phase with a time interval of 36500 days (100 years).
4. A load of -100 kPa is applied at the top with time interval zero.
5. A staged construction phase with a time interval of 100 days. Use the “reset displacements to zero” option.

Start the calculation and ignore the warning about calculation phases with zero time interval.

Figure 2 shows a graph of the displacements vs. time for a node in the sample. The additional resting time of phase 3 increased the OCR from 1 to approximately 2.4 resulting in a stiffer behaviour of the sample as can be seen from the figure.

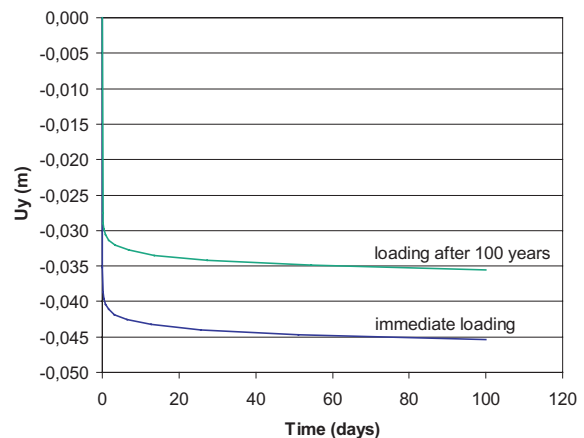


Figure 2: Time - settlement curve.