PRACTICAL APPLICATION OF THE SOFT SOIL CREEP MODEL – PART II

D. Waterman, Plaxis BV & W. Broere, Delft University of Technology/Plaxis BV

UNDRAINED BEHAVIOUR

In the previous issue of the Plaxis Bulletin some basic aspects of the Soft Soil Creep model have been discussed. For simplicity, the soil behaviour was limited to drained behaviour, so that the influence of the overconsolidation ratio (OCR) and the initial creep velocity could be shown clearly. However, in the real world soils that exhibit creep behaviour generally have a low permeability. These soft soils almost always show undrained behaviour under short term loading. This combination of undrained behaviour and creep raises some additional issues that will be discussed here.

In the previous Plaxis Tutorial, a square block of clay was modelled using Soft Soil Creep (SSC) material, with standard boundary conditions, initial stresses due to its own weight and no initial excess pore pressures. For the current example, we will change the material behaviour from drained to undrained, and re-examine its behaviour.

Assume first that it is possible to seal all sides of this block of soil, so that any excess pore pressures that develop can not drain off and effectively consolidation cannot occur, but deformation is not hindered. Common clingfoil will do this nicely, as will the closed consolidation boundaries that are available in Plaxis. Now leave the block of soil undisturbed for a considerable time period. After for example 10 years, the material will still be almost undeformed, but has developed significant excess pore pressures inside, even though no external load was applied.

This development of excess pore pressures in the absence of external loads or deformation is completely logical for a SSC material. Normally, creep behaviour of the soil causes plastic deformation and, as a result, a decrease in volume. However, as the material is undrained and there is no possibility to consolidate, volume strains are not allowed in the model. Therefore, the plastic volume strain that is calculated due to creep has to be compensated by an elastic volume strain of equal magnitude but opposite direction. As the total volume strain is the sum of the elastic and plastic volume strains, this results in a nett volume strain equal to zero.

According to Hooke's law, elastic expansion, a negative elastic compression, leads to a decrease of the effective stresses. But, since no external load was applied, the total stresses must remain the same, and a decrease of the effective stresses is only allowable if the excess pore pressures increase. It is this mechanism that causes the observed excess pore pressures. Of course, this mechanism will continuously increase the excess pore pressures over time, but the creep that drives it will diminish rapidly. As the creep rate depends on the effective stress level, and the excess pore pressures decrease the effective stresses in the sample, the creep rate will decrease at an even higher rate than in the case of a drained material.

The shift of stress from the effective stress part of the total stress to the (excess) pore pressures is also the cause for the very small deformation that is observed in the Plaxis model. Even though water is often assumed to be totally incompressible, it is not, and the increased pore pressures cause a very small volume strain of the pore water, and thereby of the entire model.

This is, of course, a rather theoretical example. Soil is hardly ever left completely undisturbed for 10 years in a situation where consolidation cannot occur. But this example still shows an important feature of the SSC model: creep behaviour of undrained soils leads to an increase of excess pore pressures.

Consolidation, on the other hand, deals with the dissipation of excess pore pressures over time in soils with low permeability and has the opposite effect. The combination of consolidation and creep in a creep sensitive soil can therefore cause a wide range of behaviour. The precise behaviour depends on whether creep or consolidation is dominant.

Over time, creep would tend to increase the pore pressures, causing the creep velocity to decrease and the consolidation velocity to increase. Due to consolidation the pore pressures will drop again, which causes the consolidation rate to decrease and the creep rate to increase. This combination of effects is illustrated below.

A simple 1D consolidation test has been performed on four different soil data sets, each with the same strength and stiffness parameters as listed in the previous Plaxis Bulletin, but with permeabilities varying between 0.1 m/day and 10_{-4} m/day. For this exercise closed consolidation boundaries have been added to the left and right side of the square soil block, as shown in Figure 1.

Figure 2 shows the excess pore pressure in the middle of the soil sample as a function of time. After first loading the sample with 100 kPa over a period of 1 day, the excess pore pressure is 109 kPa in all cases (100 kPa due to the load and 9 kPa due to creep during the first day). For the highest permeability (0.1 m/day) the excess pore pressures immediately drop when consolidation starts, whereas for lower permeabilities the excess pore pressures first increase for a while, until consolidation really becomes the dominant effect and the excess pore pressures finally decrease. Note that for a permeability of 10_{-4} m/day the excess pore pressures even rise to a peak value of 130 kPa after 63 days!

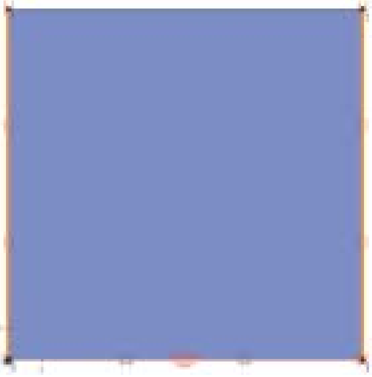

Figure 1: Geometry with closed consolidation boundaries

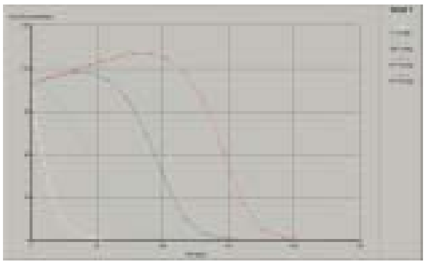

Figure 2: Development of excess pore pressures over time for the various cases