68 BRACED EXCAVATION

The following example concerns an excavation as indicated in Figure 68.1 (a). The excavation is 15 m deep and 30 m wide. The geometry is such that symmetry considerations cannot be utilized. The excavation is performed in a sequence of stages and struts are inserted at regularly intervals to eventually reach the final configuration shown in Figure 68.1 (b). The medium and dense sands

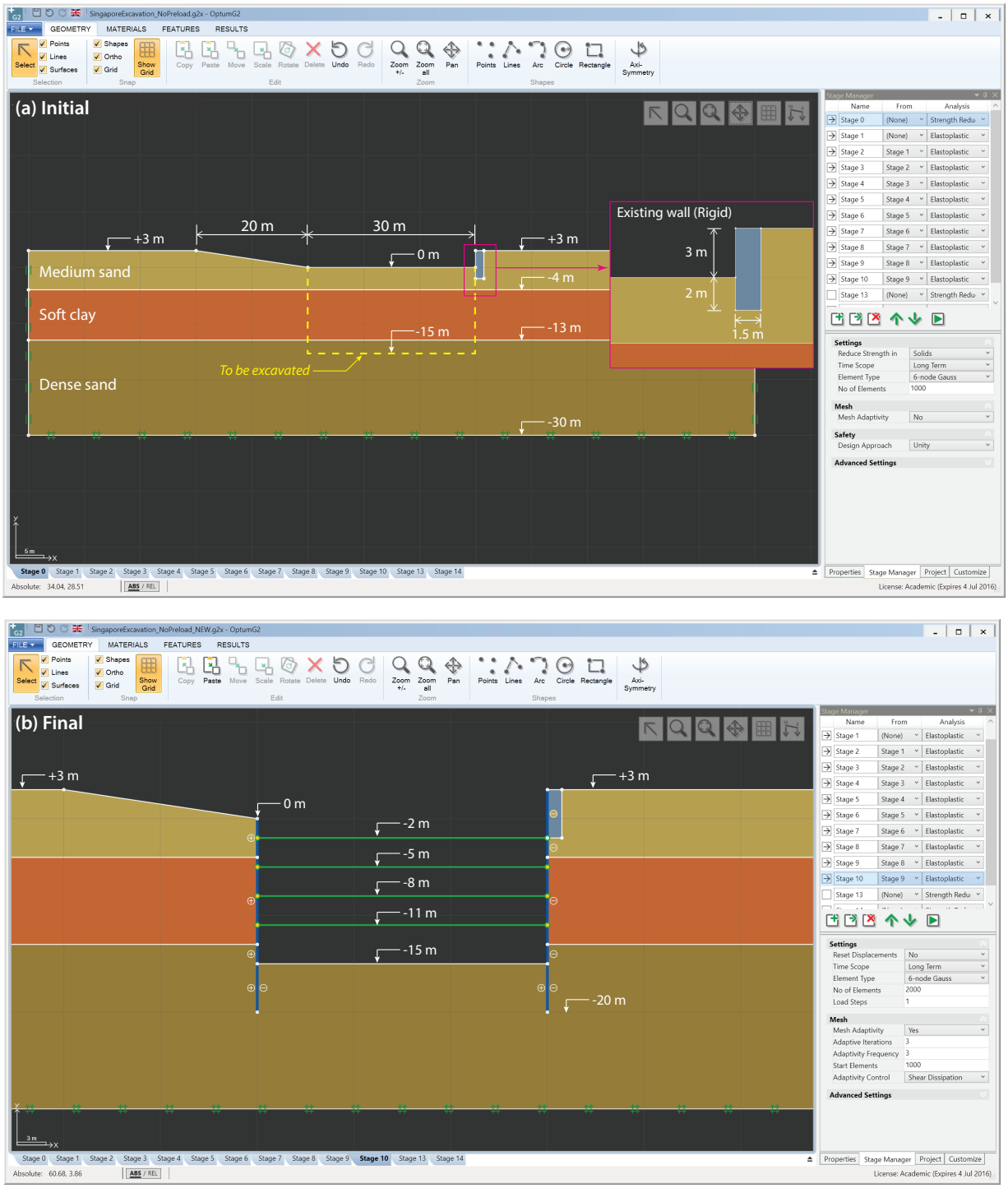

Figure 68.1: Initial (a) and final (b) configurations.

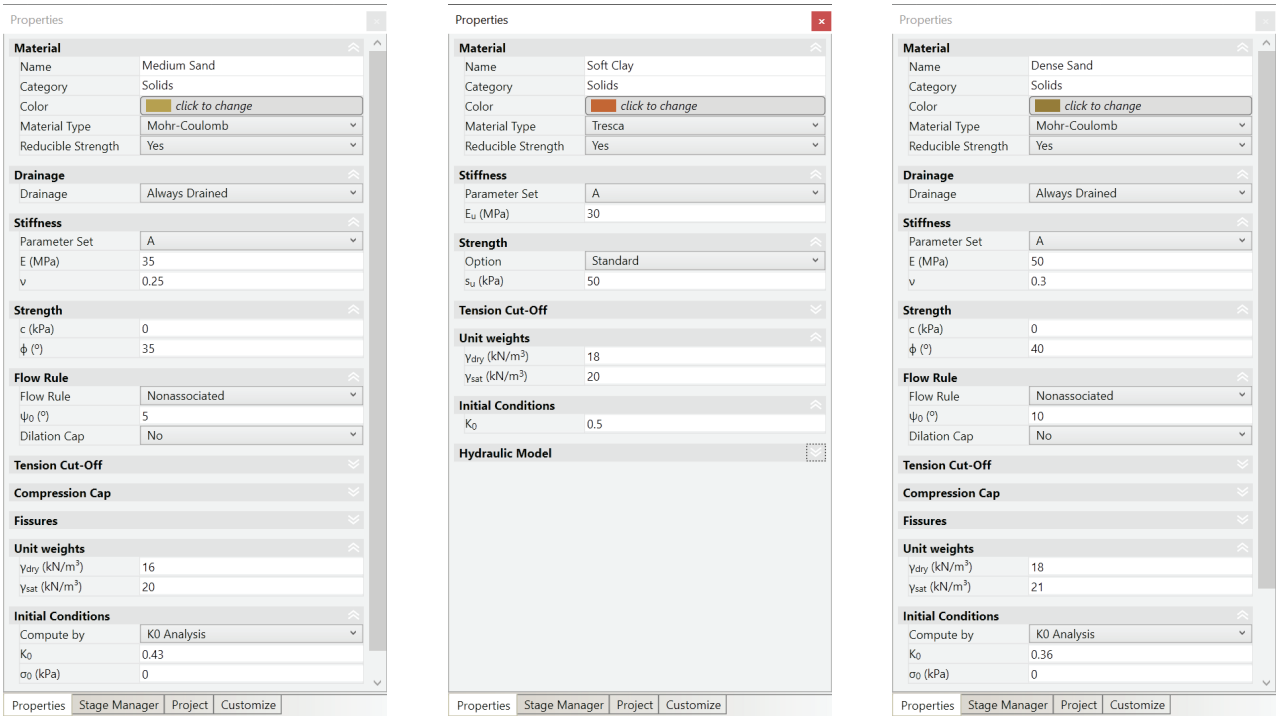

Figure 68.2: Soil materials.

are modelled as Mohr-Coulomb materials while the soft clay is modelled as a Tresca material. The parameters of the three materials are shown in Figure 68.2. The sheet piles are modelled as Plates while the struts are modelled using the Connector elements. The parameters of these elements are shown in Figure 68.3. Upon installation, the struts may or may not be preloaded. In the following both possibilities are investigated and the response of the system for each strategy are compared.

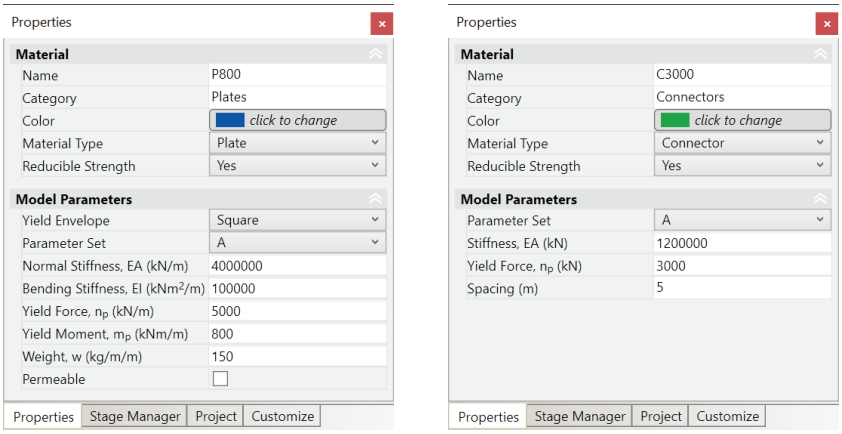

Figure 68.3: Sheet piles (Plates) and struts (Connectors).

68.1 Without preloading

We first consider the case where the struts are not preloaded. The program is summarized in Table 68.1. The first two stages (Stage 0 and 1) account for the initial stresses and the installation of the sheet piles respectively. The excavation then begins in intervals of 3 m, with a strut installed 1 m

above the current excavation level before each new excavation step. In the present analysis where no preloading is applied to the struts, the stages accounting only for the installation of the struts (Stages 3, 5, 7, 9) do not give rise to any deformations and could in principle have been combined with the subsequent excavation step, i.e. Stage 3 with Stage 4, Stage 5 with Stage 6, etc. However, for the sake of clarity, the installation of the struts have been performed in a separate stage.

Stage	Exc. level (m)	Action	Analysis Type
0	0.0	Initial stresses computed	Initial Stress
1	0.0	Sheet piles installed	Elastoplastic
2	-3.0	Excavation	Elastoplastic
3	-3.0	Strut installed at level -2 m	Elastoplastic
4	-6.0	Excavation	Elastoplastic
5	-6.0	Strut installed at level -5 m	Elastoplastic
6	-9.0	Excavation	Elastoplastic
7	-9.0	Strut installed at level -8 m	Elastoplastic
8	-12.0	Excavation	Elastoplastic
9	-12.0	Strut installed at level -11 m	Elastoplastic
10	-15.0	Excavation	Elastoplastic

Table 68.1: Definition of stages (without preloading).

68.2 With preloading

Next, we consider the case where the struts are preloaded. The program is shown in Table 68.2 and differs from the previous one only in that each of the struts are preloaded immediately upon installation, i.e. in Stages 3, 5, 7, and 9.

Stage	Exc. level (m)	Action	Analysis Type
0	0.0	Initial stresses computed	Initial Stress
1	0.0	Sheet piles installed	Elastoplastic
2	-3.0	Excavation	Elastoplastic
3	-3.0	Strut installed at level -2 m and preloaded to $-2,000$ kN	Elastoplastic
4	-6.0	Excavation	Elastoplastic
5	-6.0	Strut installed at level -5 m and preloaded to $-1,500$ kN	Elastoplastic
6	-9.0	Excavation	Elastoplastic
7	-9.0	Strut installed at level -8 m and preloaded to $-2,000$ kN	Elastoplastic
8	-12.0	Excavation	Elastoplastic
9	-12.0	Strut installed at level -11 m and preloaded to $-2,000$ kN	Elastoplastic
10	-15.0	Excavation	Elastoplastic

Table 68.2: Definition of stages (with preloading).

In OptumG2, preload (or prestress) is applied by selecting a Connector and then specifying “Apply Prestress = Yes” (see Figure 68.4). The application of preload should be seen as an action: the normal force in the Connector is set to the value specified. In this case, the relevant preloading will induce a state of compression in the struts, hence the negative value.

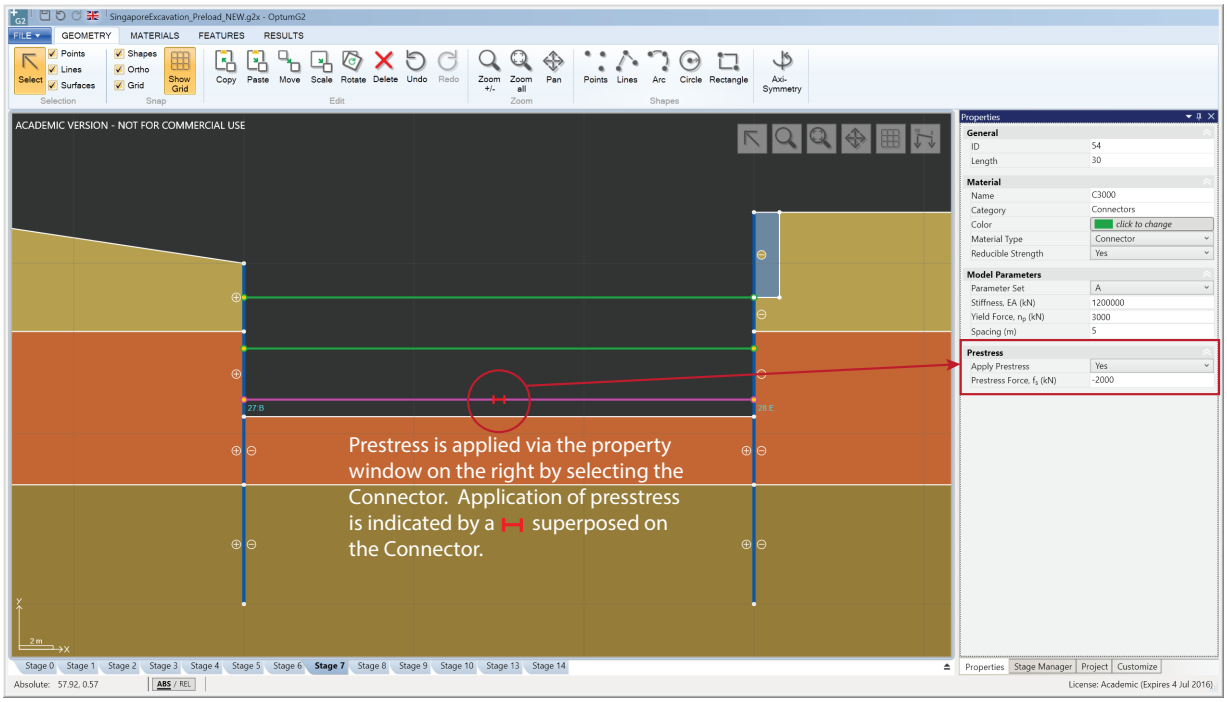

Figure 68.4: Application of preload in Stage 7.

68.3 Results

68.3.1 Factor of safety analysis

Before deformations are determined, a Strength Reduction analysis is conducted for each stage. The results, shown in Figure 68.5, reveal that the factor of safety remains above 1.9 throughout the excavation. It should be noted that preloading does not affect the factor of safety.

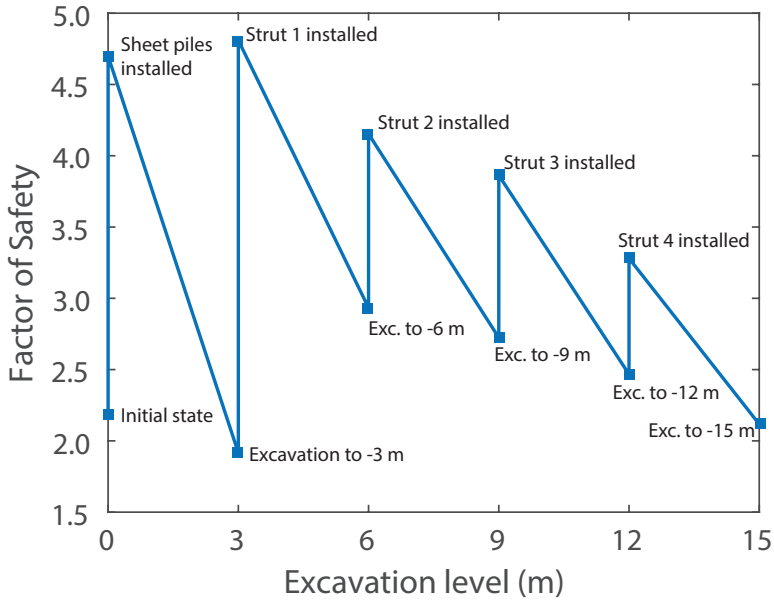

Figure 68.5: Factor of safety versus excavation level.

68.3.2 Displacements

With a reasonable level of safety against failure verified, the next step is to determine deformations according to the programs outlined in Tables 68.1-2.

The displacement fields at the final stage for the two cases – with and without preloading of the struts – are shown in Figure 68.6.

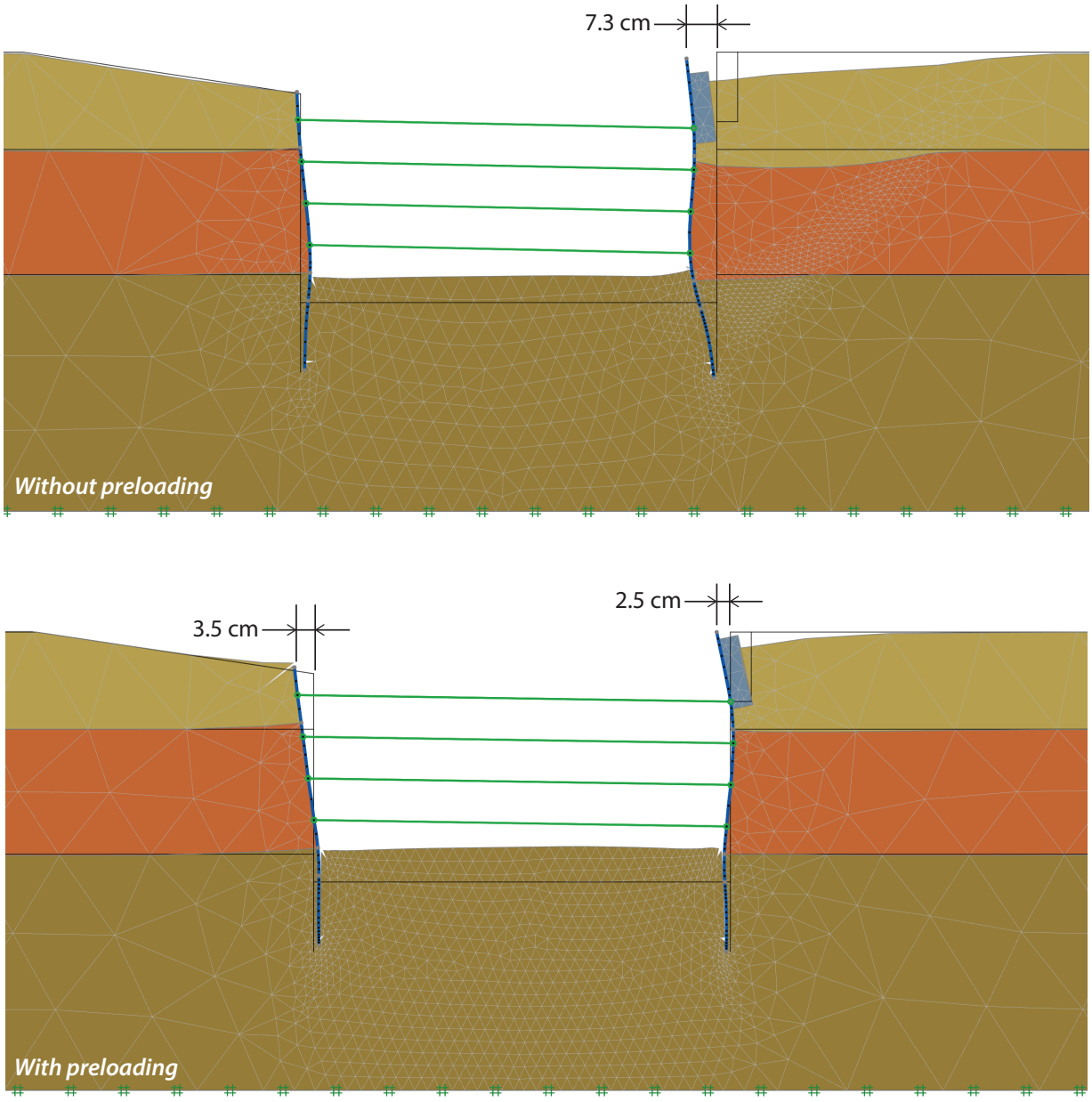

Figure 68.6: Final configurations without (top) and with (bottom) preloading of struts.