



Developed by Ce.A.S. srl, Italy and Deep Excavation LLC, U.S.A.

Soil modelling in Paratie

The next document contains any information and direction to follow in Paratie Plus in order to configure different soil constitutive models.

Here is a comparison with Paratie 7.0 controls.

Refer to the following table:

Clays mechanical behaviour (notes)	
ASSUMING DRAINED CONDITIONS ...	ASSUMING UNDRAINED CONDITIONS
<ul style="list-style-type: none">• Always with granular soil (sand or gravel)• Always with cohesive soil having a considerable percentage of silt• When long term checking a cohesive soil	<ul style="list-style-type: none">• When short term (2-3 months) checking cohesive soil• When the wall is temporary

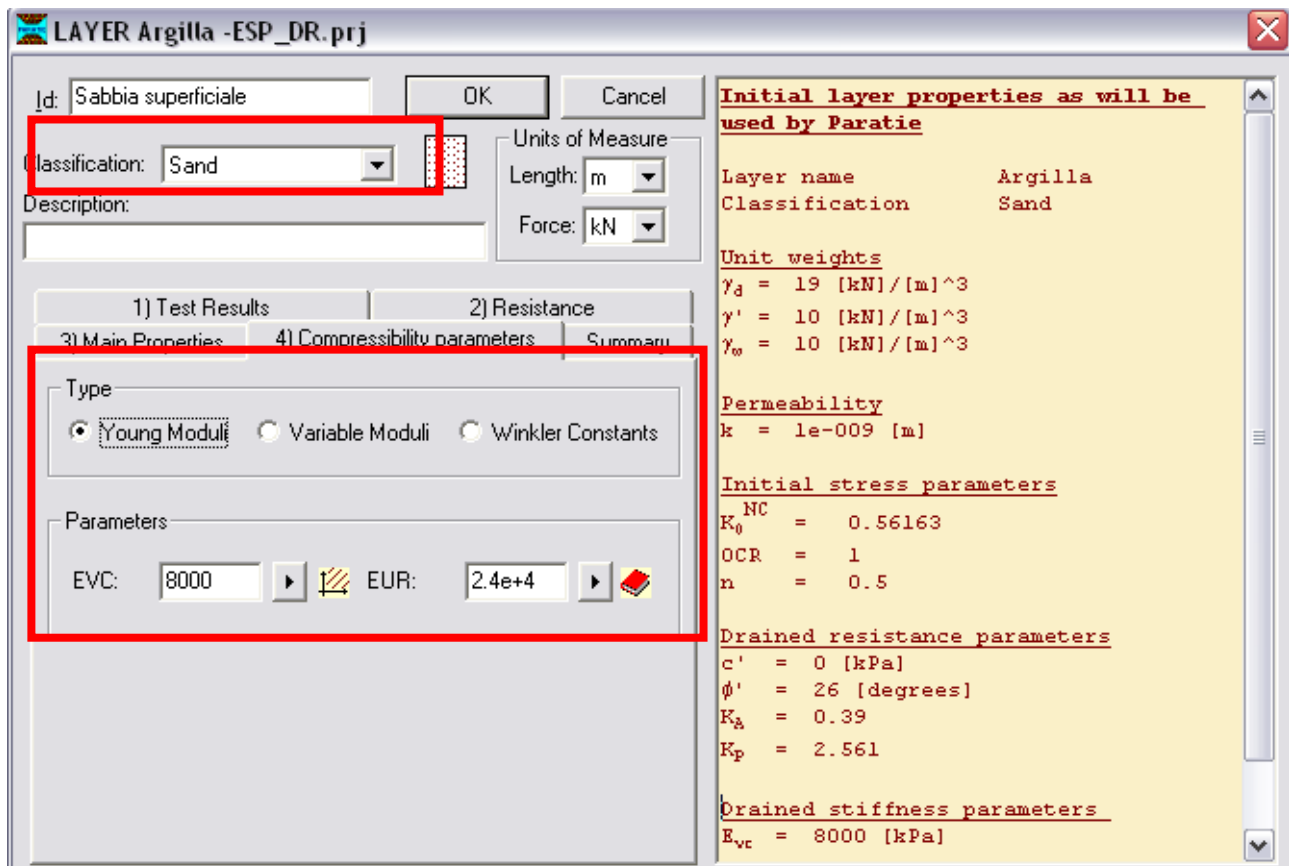
The following soil constitutive models are available in Paratie (both in the previous versions and in Paratie Plus):

- ✓ Granular soil constitutive model (always drained conditions)
- ✓ Coesive soil constitutive model (drained or undrained conditions) using effective stresses – ESP.
- ✓ Coesive soil constitutive model (undrained conditions) using total stresses – ESP.

- **Drained conditions for granular soil**

In Paratie 7.0 the user chose the kind of soil in the soil window. To use granular soil it was enough to select *sand*.

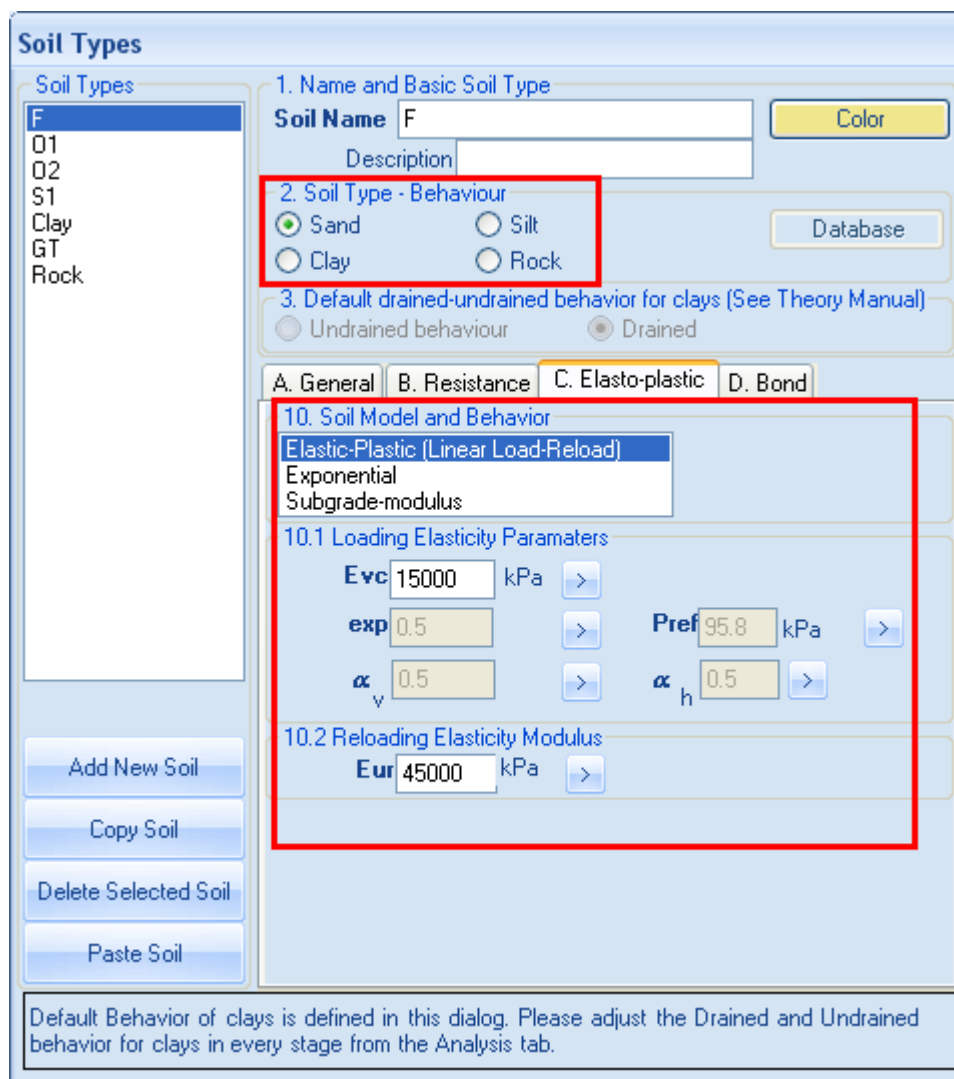
Choosing a *sand* soil the supposed behaviour was always drained.



Selecting a *sand* soil it was possible to chose among three different options:

1. Give two modulus E_{vc} e E_{ur} (elastic vergin compression modulus and elastic unload-reload modulus) constant with depth.
2. Consider elastic modulus variable with depth and depending on external pressure.
3. Give directly Winkler stiffness

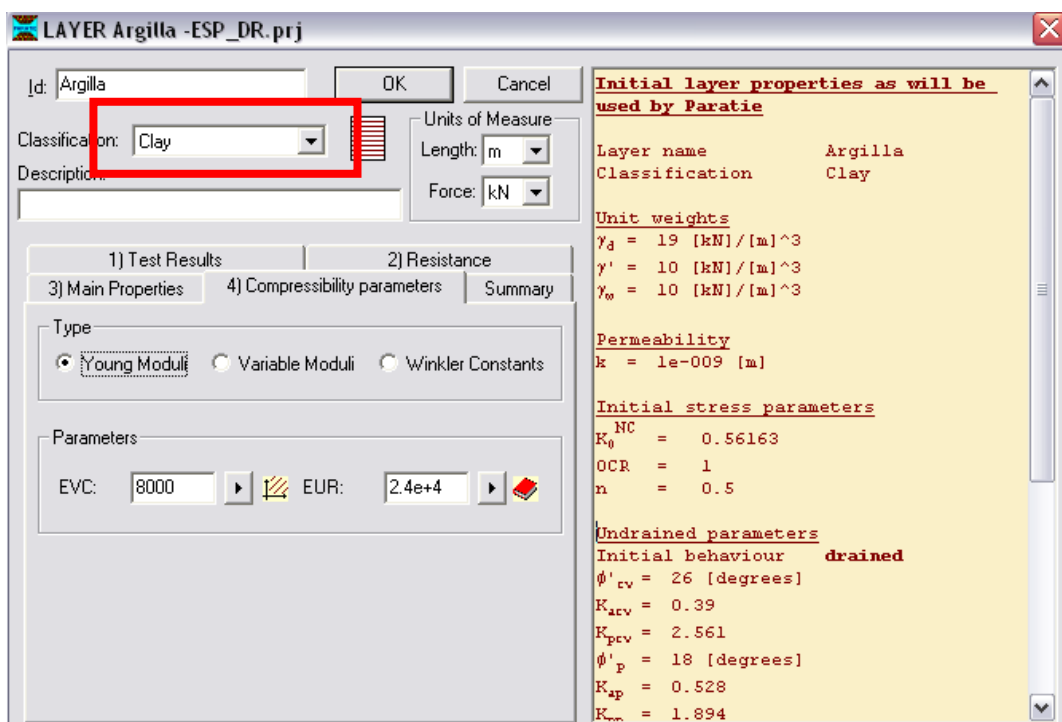
In a similar way the user can set the same options in Paratie Plus:



Silt and *rock* soils are modelled like a sand soil. Selecting then *silt* or *rock* only conventional analysis results are affected and, using *rock*, the embedment check in non-linear analysis.

- **Coesive soil – Drained and undrained conditions**

Selecting *Clay* in Paratie 7.0, the cohesive soil constitutive model is activated.



The same is in Paratie Plus:



Selecting a Clay constitutive model the user can choose to consider the soil drained or undrained and to use an ESP or TSP model. (cfr Theory manual)

The following table summarizes every possible configuration:

		A	B
	MODEL	DRAINED	UNDRAINED
1	ESP (Effective stress path)	YES	YES
2	TSP (Total stress path)	NO	YES

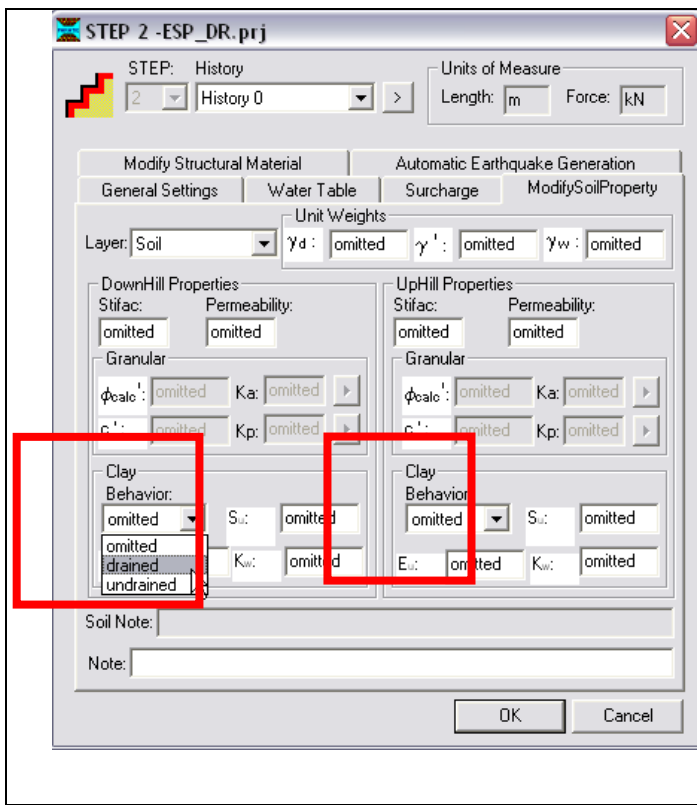
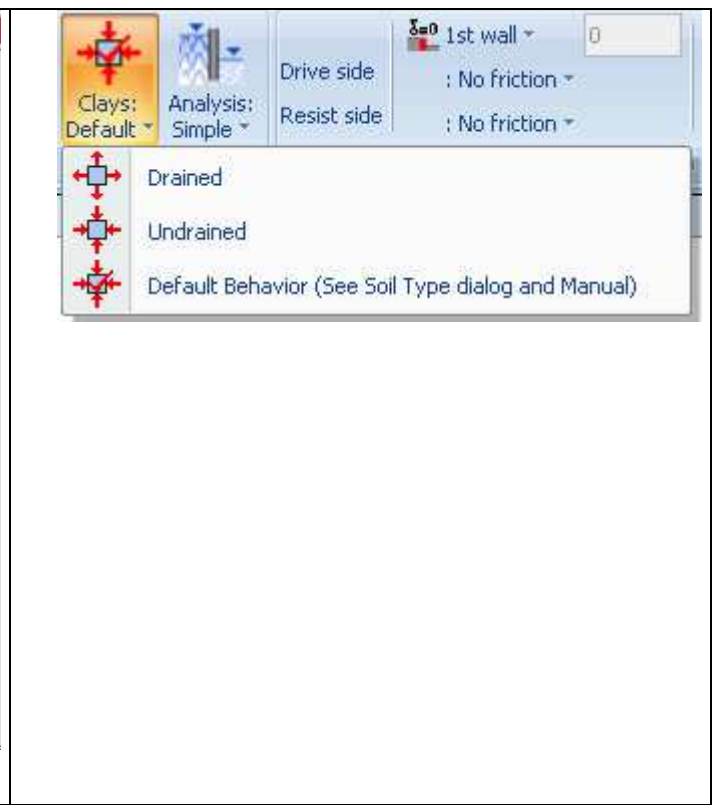
Configurations A –1 e B-1 (ESP MODEL):

Select the initial behaviour:

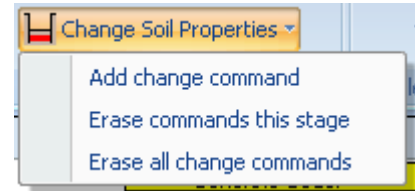
The screenshot displays the software interface for defining a layer. On the left, the 'Initial Behaviour' section is highlighted with a red box, showing the 'Drained' radio button selected. Below it, the 'Effective Resistance Parameters' section contains fields for δ/ϕ , ϕ'_{cv} , $K_{s,cv}$, ϕ'_p , and $K_{s,p}$. The 'Undrained Parameters' section includes S_u , E_u , and K_w .

On the right, the 'Soil Type' section is highlighted with a red box, showing 'Clay' selected and 'Drained' behavior chosen. Below this, the 'General' tab is active, showing parameters for Unit Weights, Strength Parameters, Permeability, and Minimum Pressures.

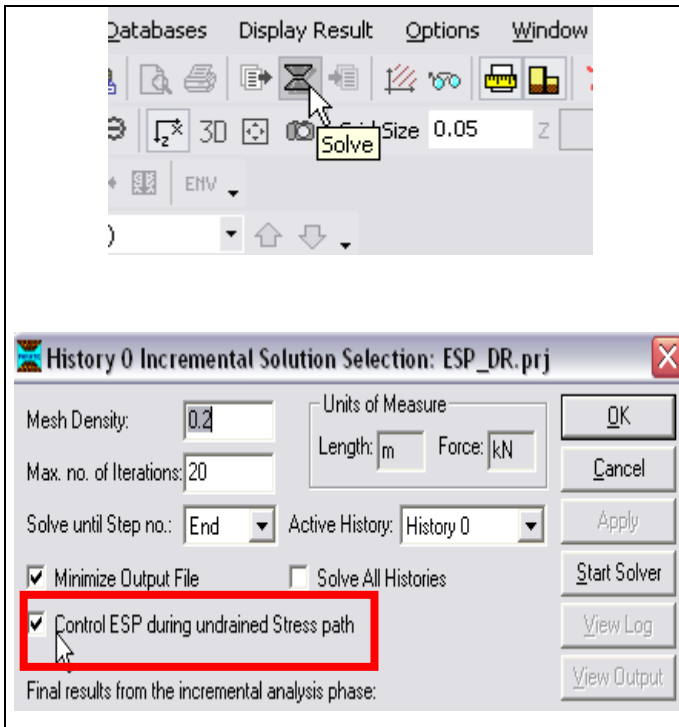
If necessary the user can modify stage by stage clays behaviour through this window:

	
	<p>When the user modifies clays behaviour under <i>Analysis</i> menu, the changes regard both uphill and downhill ground, for the actual stage. Selecting <i>Default</i> the behaviour will be the one defined in the <i>Edit sol tipe data</i> window. To distinguish between uphill and downhill ground behaviour use the</p>

option *Model/Advanced/Change soil Properties*:



Configure ESP before starting the analysis:



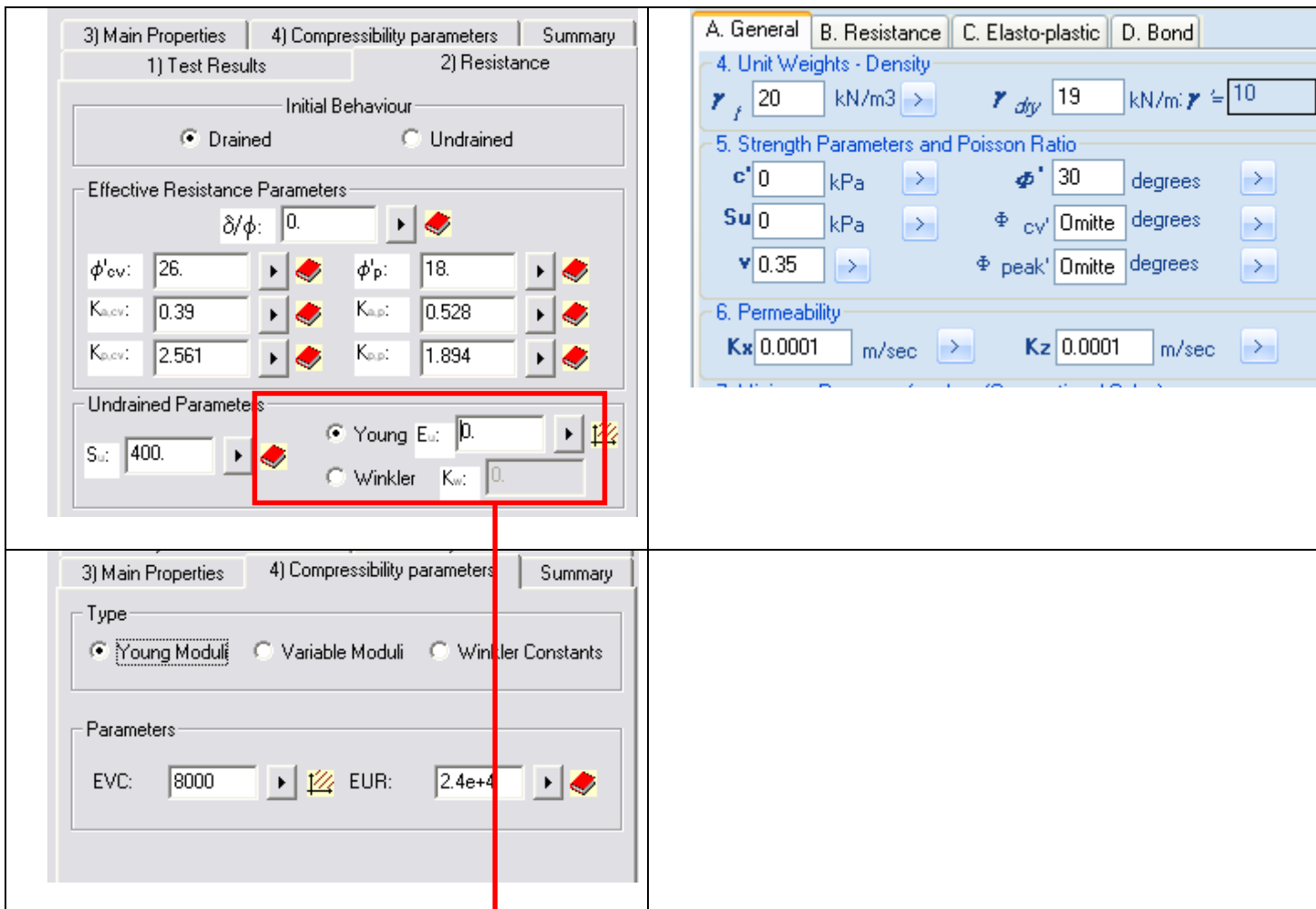
In Paratie Plus it is a default option.

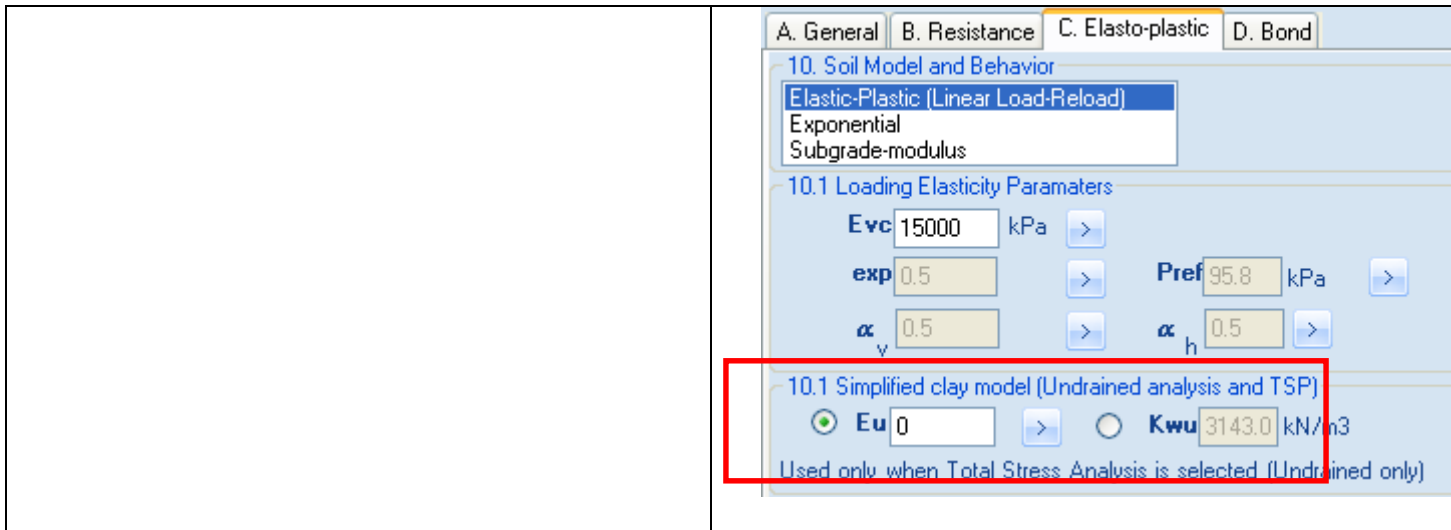
Concrete Code:	EC2-2004
Steel Code:	EC3-2005
Non linear	Assumptions: ESP
Drain State Clays	Default
Water q= 10 kN/m3	Simple flow
Adv. NL surcharge method	Beta= 45 deg
Drive Ka	Rankine (Coul. d=0)
Resist Kp	Rankine (Coul. d=0)
1st Wall classic	Assumptions
Water q= 10 kN/m3	Simple flow
Drive	Ka
Resist	Kp

The ESP constitutive model allows to change the soil behaviour from drained to undrained (and vice versa) during any stage.

If an ESP model has been chosen the parameters in the red frame (in the following figure) are not to be considered.

The S_u parameter in ESP model is not essential, it is used as external border of the elasto-plastic field (refer to the documents included into the installation folder or page 14).



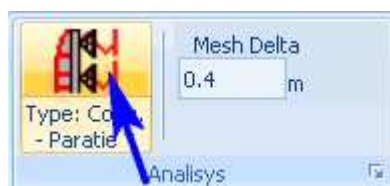


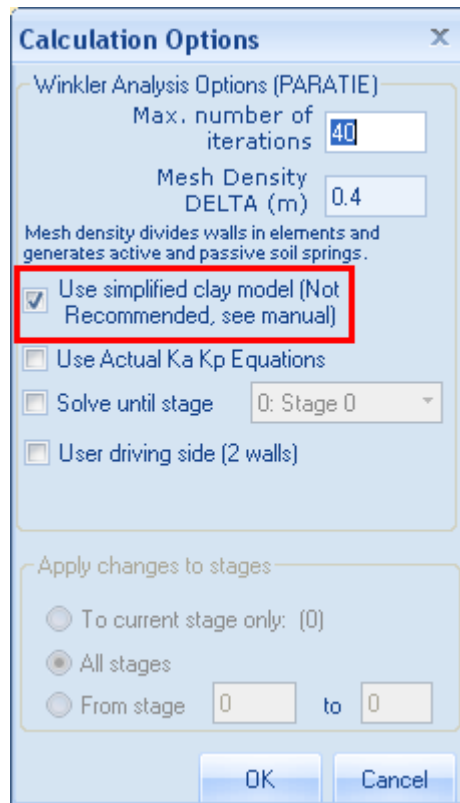
This parameters are ignored by the ESP model.

Elastic modulus used are the same of the sand model.

Configurations B-2 e B-1 (TSP MODEL):

Under Analysis menu it's possible to set TSP model:



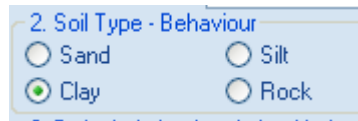


Selecting the option in the red frame, the yellow window will be updated:

Concrete Code:	EC2-2004
Steel Code:	EC3-2005
Non linear	Assumptions: TSP
Drain State Clays	Default
Water $q=10$ kN/m ³	Simple flow
Adv. NL surcharge method	Beta= 45 deg
Drive K_a	Rankine (Coul. $d=0$)
Resist K_p	Rankine (Coul. $d=0$)
1st Wall classic	Assumptions
Water $q=10$ kN/m ³	Simple flow
Drive	K_a
Resist	K_p

TSP model has one plain limit: it is impossible to turn from an undrained to a drained condition (effective stresses are lost).

So, in order to analyze a model composed by n drained stages and following m undrained stages (THIS is possible), the user can select the same functions senn for the ESP model:

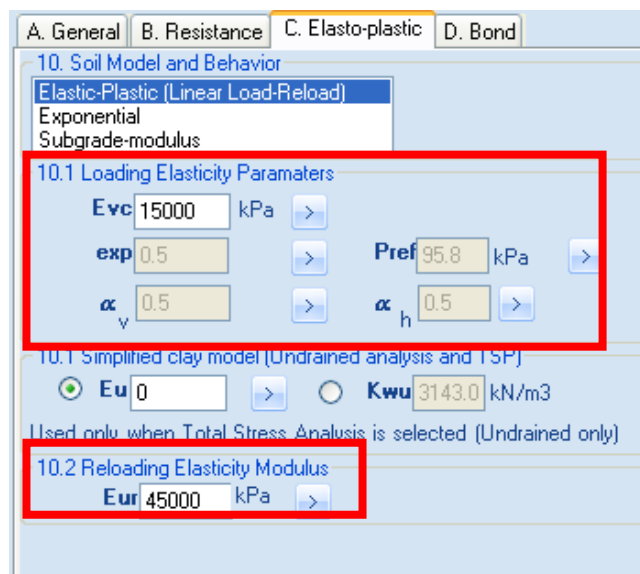


and in all m undrained stages:

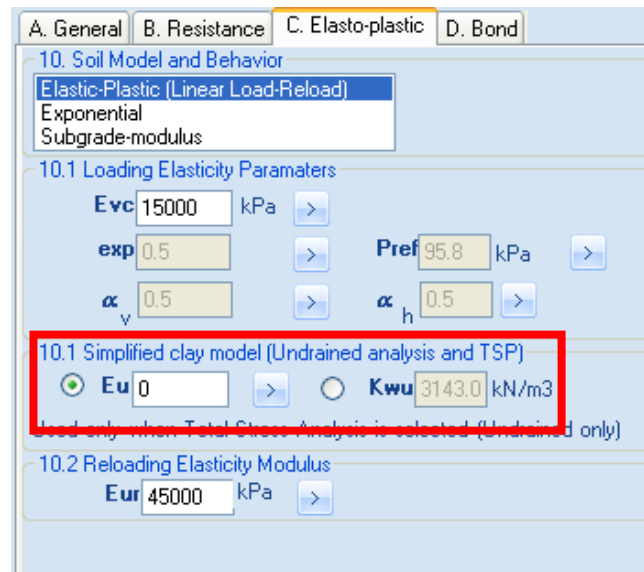


If, after an undrained stage, a drained stage is setted the model will surely collaps!

The solver launches, for the first n drained stages, th ESP model and then the used soil elastic modulus will be:

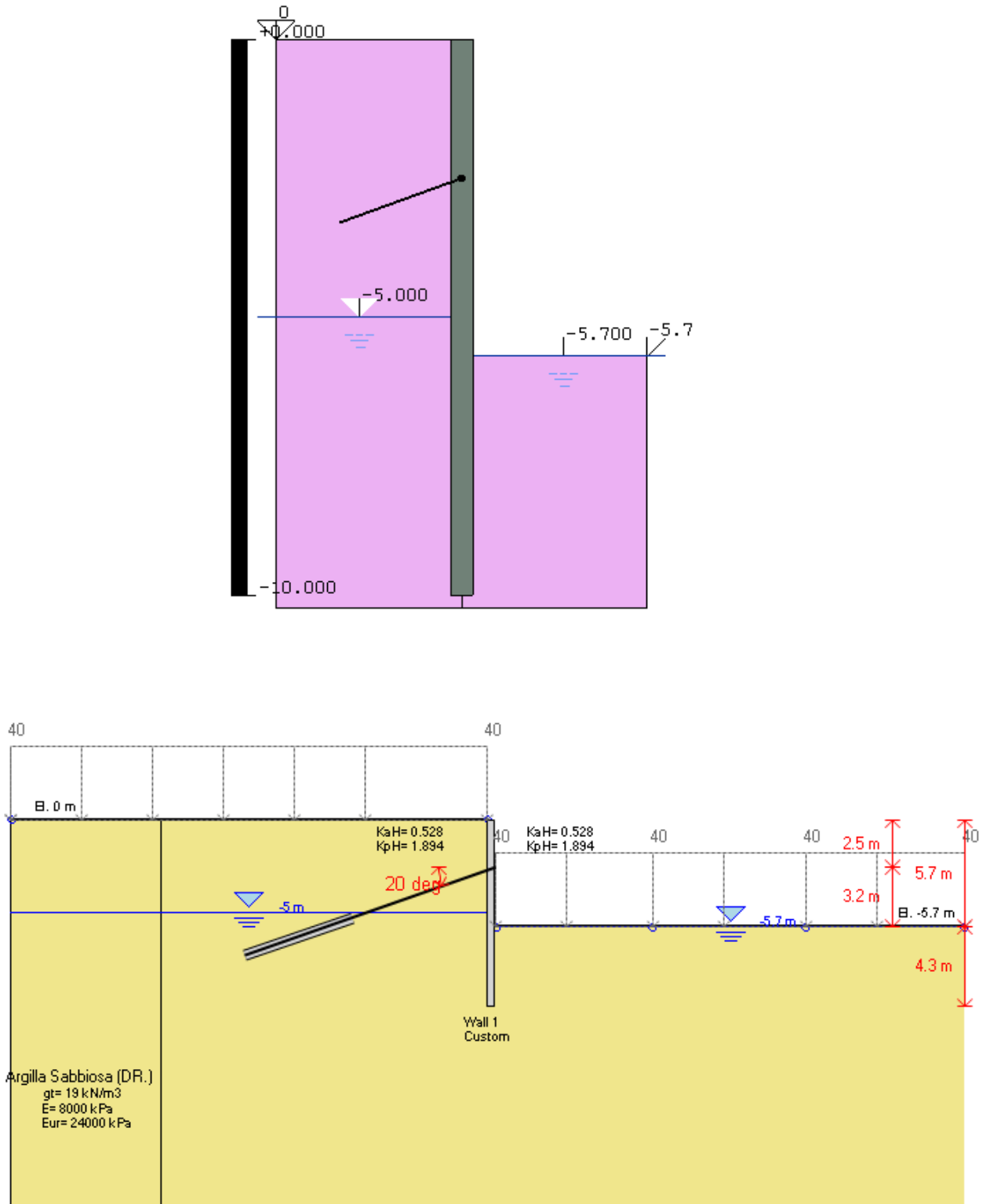


The soil elastic modulus used for the m undrained stages will be:



During the undrained steps, S_u has now an essential role if a TSP model has been chosen.

COMPARISON BETWEEN CLAY ESP MODEL IN PARATIE 7.0 AND PARATIE PLUS



Stages:

Overconsolidation	Drained
Geostatic step	Drained
1° excavation	Undrained
Tieback	Undrained
2° excavation	Undrained
Long term	Drained

The image shows two panels of a software interface. The left panel contains input fields for various soil parameters, and the right panel shows the resulting parameter values and model type.

Left Panel (Input Parameters):

- 4. Unit Weights - Density:** γ_f 19 kN/m³, γ_{dry} 19 kN/m³, $\gamma' = 9$
- 5. Strength Parameters and Poisson Ratio:** c' 0 kPa, ϕ' 0 degrees, S_u 400 kPa, ϕ_{cv} 26 degrees, ν 0.35, ϕ_{peak} 18 degrees
- 6. Permeability:** K_x 1E-09 m/sec, K_z 1E-09 m/sec
- 7. Minimum Pressures for clays (Conventional Calcs):** Min sh' 0 kPa, Min Ka 0
- 8. Include soil in parameter variation:** Include in parameter variation (i.e. Eurocode, Statistical analysis). It is strongly recommended to keep this option checked.
- 10. Soil Model and Behavior:** Elastic-Plastic (Linear Load-Reload)
- 10.1 Loading Elasticity Parameters:** E_{vc} 8000 kPa, exp 0.5, α_v 0.5, $Pref$ 950 kPa, α_h 0.5
- 10.1 Simplified clay model (Undrained analysis and TSP):** Eu 0, K_{wu} 3143.0 kN/m³
- 10.2 Reloading Elasticity Modulus:** E_{ur} 24000 kPa

Right Panel (Output Parameters and Model Type):

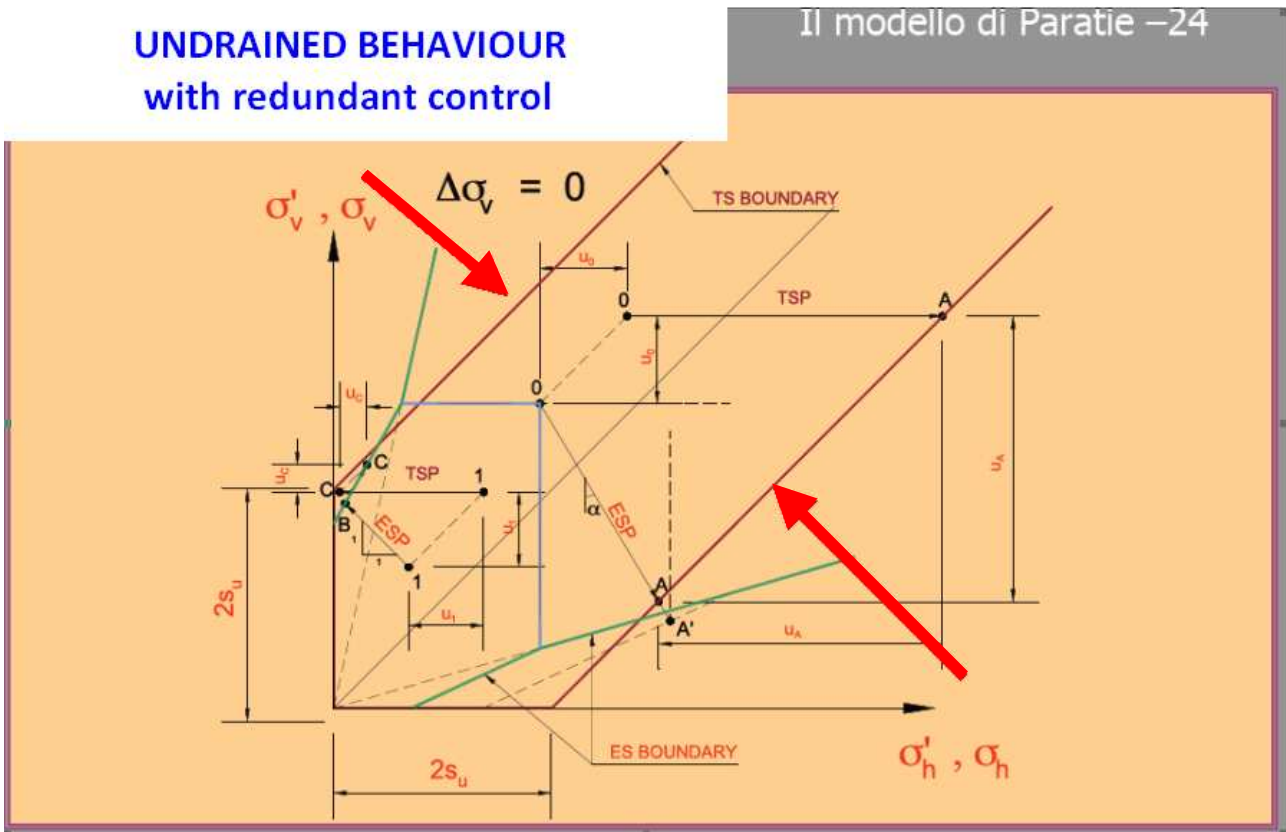
- Initial Behaviour:** Drained, Undrained
- Effective Resistance Parameters:** δ/ϕ 0, ϕ'_{cv} 26, ϕ'_p 18, $K_{a,cv}$ 0.39, $K_{a,p}$ 0.528, $K_{o,cv}$ 2.561, $K_{o,p}$ 1.894
- Undrained Parameters:** S_u 400, Young E_u 0, Winkler K_w 0
- Type:** Young Moduli, Variable Moduli, Winkler Constants
- Parameters:** EVC: 8000, EUR: 2.4e+4

Red arrows indicate the flow of data from the input fields in the left panel to the corresponding output fields in the right panel.

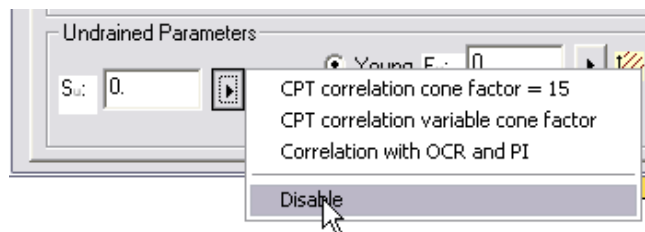
Su has been setted as 400 kPa; this means NOT to consider it; that is to put a very far from the boundary limit to the elasto-plastic field.

UNDRAINED BEHAVIOUR with redundant control

Il modello di Paratie -24



In fact in Paratie 7.0, when the user selected disable:

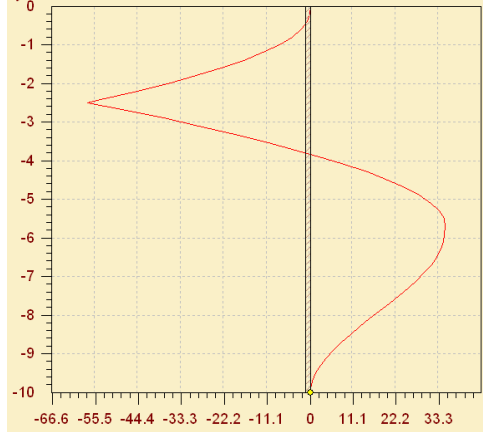
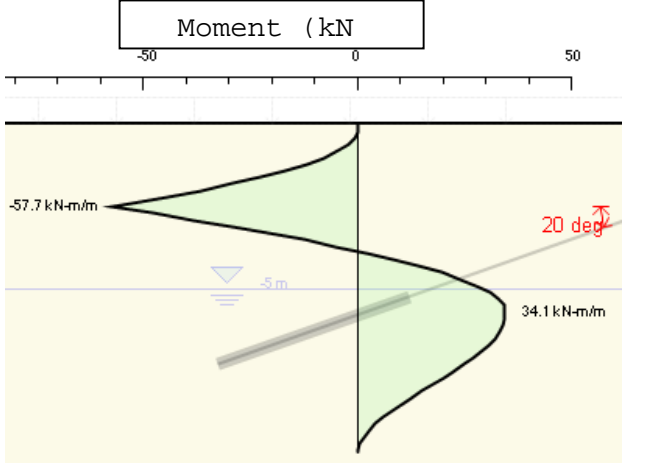
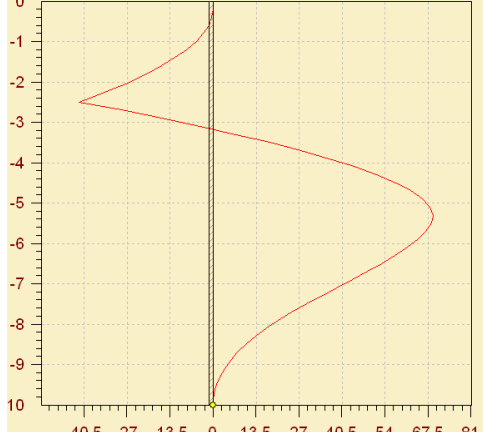
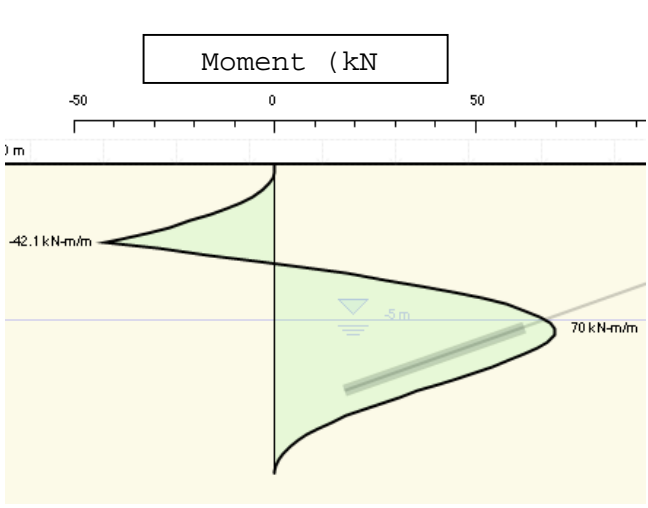


the parameter was brought to a very high value.

This option (disable) is no longer available in Paratie Plus, because Su could be used by the conventional analysis.

The measure than is to force a high value (write 400kPa).

STAGE	DISPLACEMENTS	
<p>2° excavation</p>	<p style="text-align: center;">Argille ESP History 0 - WALL LeftWall: DISPLACEMENTS AT STEP 5</p> <p style="text-align: right;">— Y-DISPLACEMENT [m]</p> <p>Max x = 0.0072019 z = -10.000000</p> <p>Min x = -0.00024334 z = 0.000000</p>	<p style="text-align: center;">Deflection</p> <p style="text-align: right;">0.72 cm</p>
<p>L.T.</p>	<p style="text-align: right;">— Y-DISPLACEMENT [m]</p> <p>Max x = 0.0061751 z = -7.300000</p> <p>Min x = 0.00039115 z = 0.000000</p>	<p style="text-align: center;">Deflection</p> <p style="text-align: right;">0.63 cm</p>

STAGE	MOMENTS	
2° excavation	 <p style="color: red;">— MOMENT [kN·m/m]</p> <p>Max x = 34.72 z = -5.700000</p> <p>Min x = -57.661 z = -2.500000</p>	 <p>Moment (kN)</p> <p>-50 0 50</p> <p>-57.7 kN·m/m</p> <p>34.1 kN·m/m</p> <p>20 deg</p> <p>-5m</p>
L.T.	 <p style="color: red;">— MOMENT [kN·m/m]</p> <p>Max x = 69.031 z = -5.300000</p> <p>Min x = -42.066 z = -2.500000</p>	 <p>Moment (kN)</p> <p>-50 0 50</p> <p>-42.1 kN·m/m</p> <p>70 kN·m/m</p> <p>-5m</p>

COMPARISON BETWEEN CLAY TSP MODEL IN PARATIE 7.0 AND PARATIE PLUS

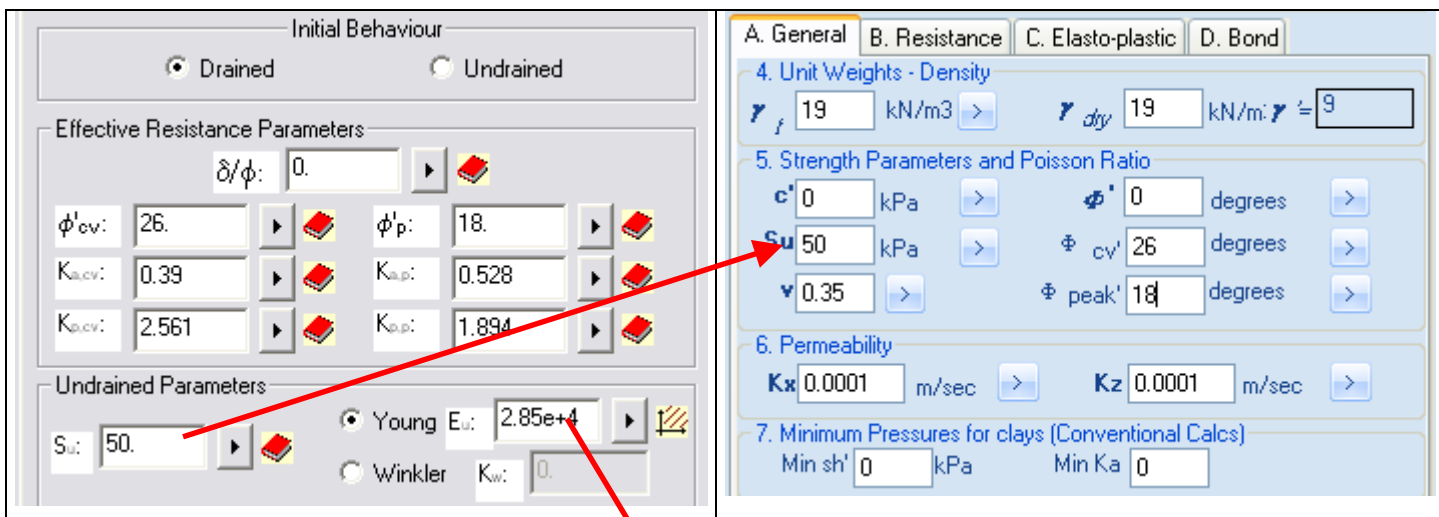
Consider now the same model seen before: this will be analyzed using a TSP model.

The last drained stage must be removed (using a TSP model it is impossible to turn from undrained to drained behaviour).

The essential parameters for TSP model are:

- S_u
- E_u (or k_w)

Then:



The screenshot shows two panels of the software interface. The left panel, titled 'Initial Behaviour', has 'Drained' selected. Under 'Effective Resistance Parameters', δ/ϕ is 0. Under 'Undrained Parameters', S_u is 50, E_u is $2.85e+4$, and 'Young' is selected. The right panel, titled 'A. General', has 'B. Resistance' selected. Under '5. Strength Parameters and Poisson Ratio', S_u is 50 kPa, ϕ_{cv} is 26 degrees, and ϕ_{peak} is 18 degrees. A red arrow points from the S_u field in the left panel to the S_u field in the right panel.



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<p>Type</p> <p><input checked="" type="radio"/> Young Moduli <input type="radio"/> Variable Moduli <input type="radio"/> Winkler Constants</p> <hr/> <p>Parameters</p> <p>EVC: <input type="text" value="8000"/> <input type="button" value="▶"/> <input type="button" value="⚙️"/> EUR: <input type="text" value="2.4e+4"/> <input type="button" value="▶"/> <input type="button" value="📄"/></p>	<p>A. General B. Resistance C. Elasto-plastic D. Bond</p> <p>10. Soil Model and Behavior</p> <p>Elastic-Plastic (Linear Load-Reload) Exponential Subgrade-modulus</p> <p>10.1 Loading Elasticity Parameters</p> <p>Evc <input type="text" value="8000"/> kPa <input type="button" value="▶"/></p> <p>exp <input type="text" value="0.5"/> <input type="button" value="▶"/> Pref <input type="text" value="95.8"/> kPa <input type="button" value="▶"/></p> <p>α_v <input type="text" value="0.5"/> <input type="button" value="▶"/> α_h <input type="text" value="0.5"/> <input type="button" value="▶"/></p> <p>10.1 Simplified clay model (Undrained analysis and TSP)</p> <p><input checked="" type="radio"/> Eu <input type="text" value="28500"/> <input type="button" value="▶"/> <input type="radio"/> Kwu <input type="text" value="0"/> kN/m3</p> <p>Used only when Total Stress Analysis is selected (Undrained only)</p> <p>10.2 Reloading Elasticity Modulus</p> <p>Eur <input type="text" value="24000"/> kPa <input type="button" value="▶"/></p>
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Stages:

Overconsolidation	Drained
Geostatic step	Undrained
1° excavation	Undrained
Tieback	Undrained
2° excavation	Undrained

STAGE	DISPLACEMENTS	
Tieback	<p>— Y-DISPLACEMENT [m]</p> <p>Max x = 0.0028625 z = -10.000000</p> <p>Min x = 0.001331 z = -2.000000</p>	<p>Deflection</p> <p>0</p> <p>5 m</p> <p>p 100 kN/m</p> <p>0.29 cm</p>
2° excavation	<p>— Y-DISPLACEMENT [m]</p> <p>Max x = 0.0067079 z = -9.300000</p> <p>Min x = 0.0013802 z = 0.000000</p>	<p>Deflection</p> <p>0</p> <p>5 m</p> <p>0.67 cm</p>

STAGE	MOMENTS	
Tieback	<p style="text-align: right;">— MOMENT [kN·m/m]</p> <p>Max x = 14.857 z = -5.900000</p> <p>Min x = -51.78 z = -2.500000</p>	<p style="text-align: center;">Moment (kN)</p> <p style="text-align: center;">-50 0</p> <p style="text-align: center;">-51.8 kN-m/m 14.9 kN-m/m</p> <p style="text-align: center;">-5m</p> <p style="text-align: center;">p 100 kN/m</p>
2° excavation	<p style="text-align: right;">— MOMENT [kN·m/m]</p> <p>Max x = 56.239 z = -5.100000</p> <p>Min x = -43.743 z = -2.500000</p>	<p style="text-align: center;">Moment (kN)</p> <p style="text-align: center;">-50 0 50</p> <p style="text-align: center;">0 m</p> <p style="text-align: center;">-43.7 kN-m/m 58.2 kN-m/m</p> <p style="text-align: center;">-5m</p> <p style="text-align: center;">p 100 kN/m</p>