

Undrained Shear Strength Additional Note and Examples

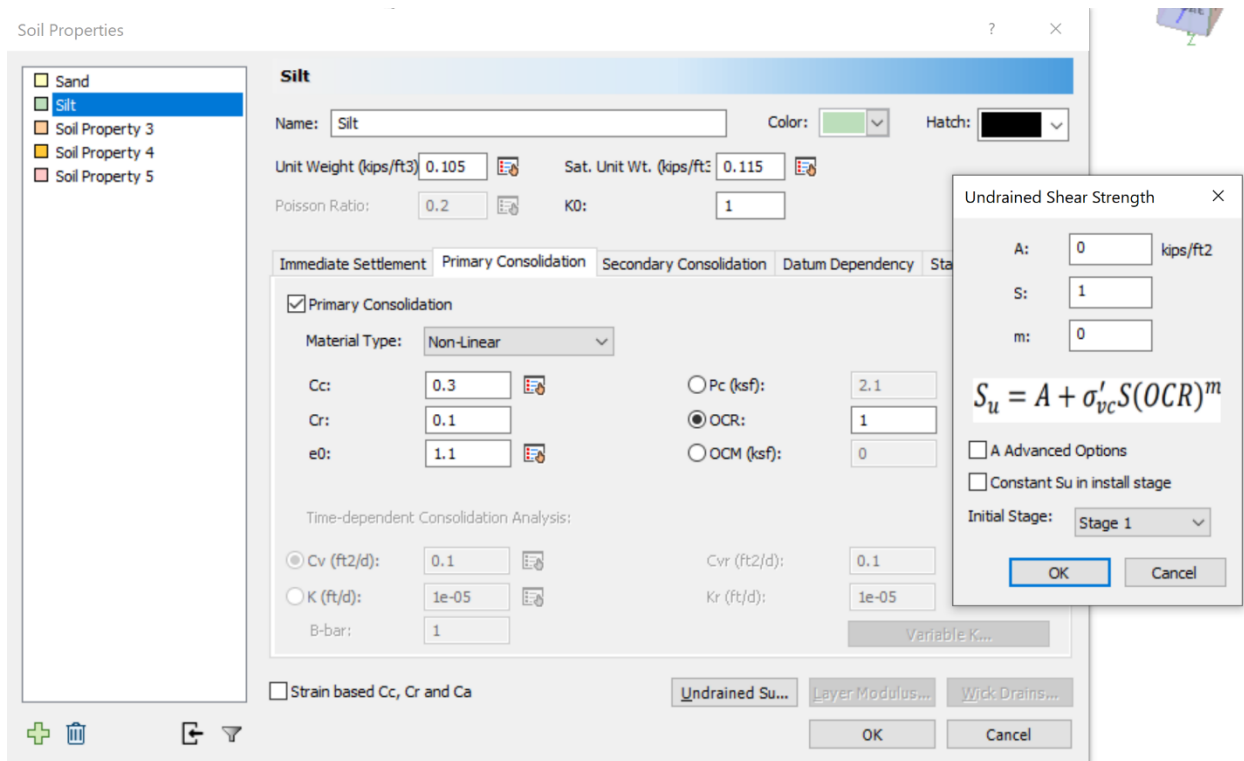
Introduction

This document provides additional resource that you will find helpful for undrained shear strength feature in Settle3. For more information on the feature itself, please refer to our online documentation [here](#):

Note that this feature is only for post-processing purposes. This feature does not affect the analysis but provides an additional output result for the user with the undrained shear strength using Shansep method. For more details on the equations, you can find it in our theory manual.

Model description

The model we'll be looking into in this document is a simple single layer model with the following material properties shown below:



The screenshot displays the 'Soil Properties' dialog box for a material named 'Silt'. The 'Primary Consolidation' tab is active, showing a 'Non-Linear' material type. The following parameters are defined:

- Name: Silt
- Unit Weight (kips/ft³): 0.105
- Sat. Unit Wt. (kips/ft³): 0.115
- Poisson Ratio: 0.2
- K0: 1
- Material Type: Non-Linear
- Cc: 0.3
- Cr: 0.1
- e0: 1.1
- OCR: 1 (selected)
- Time-dependent Consolidation Analysis:
 - Cv (ft²/d): 0.1
 - K (ft/d): 1e-05
 - B-bar: 1
 - Cvr (ft²/d): 0.1
 - Kr (ft/d): 1e-05

The 'Undrained Shear Strength' sub-dialog is also shown, displaying the following parameters:

- A: 0 kips/ft²
- S: 1
- m: 0
- Equation: $S_u = A + \sigma'_{vc} S(OCR)^m$
- Initial Stage: Stage 1

The material has non-linear method with:

Cc = 0.3, Cr = 0.1, e0 = 1.1 , and OCR of 1.

The undrained shear strength parameters are defined as below:

Case 1) A = 0, S = 1, m = 0.

In our Undrained Shear Strength documentation, the basic equation employed for undrained shear strength is shown below:

$$S_u = A + S_{u_{calc}}$$
$$S_u = A + \sigma'_{vc} S (OCR)^m$$

Where

A = Initial shear strength (S_{u0}), which can be depth-dependent

σ'_{vc} = Vertical consolidation stress

S = undrained strength ratio at OCR = 1 (In range between 0 to 1)

OCR = over-consolidation ratio (σ'_p / σ'_v)

m = strength rebound exponent (in range between 0 to 1)

of which the parameters A, S and m are the input parameters in Settle3.

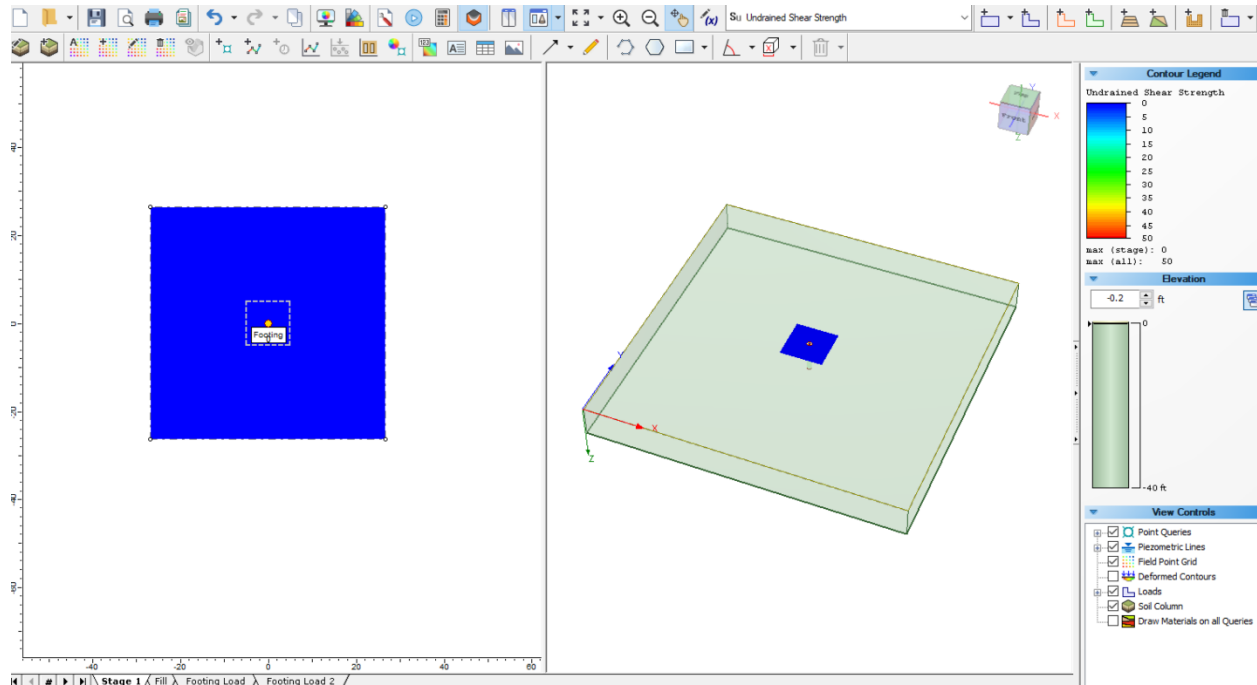
For the parameters chosen for this specific example, we're expecting to see only the parameter S to be shown in the results, which should equal to:

$$S_u = A + \sigma'_{vc} S (OCR)^m$$
$$S_u = 0 + \sigma'_{vc} 1 (OCR)^0$$
$$S_u = \sigma'_{vc}$$

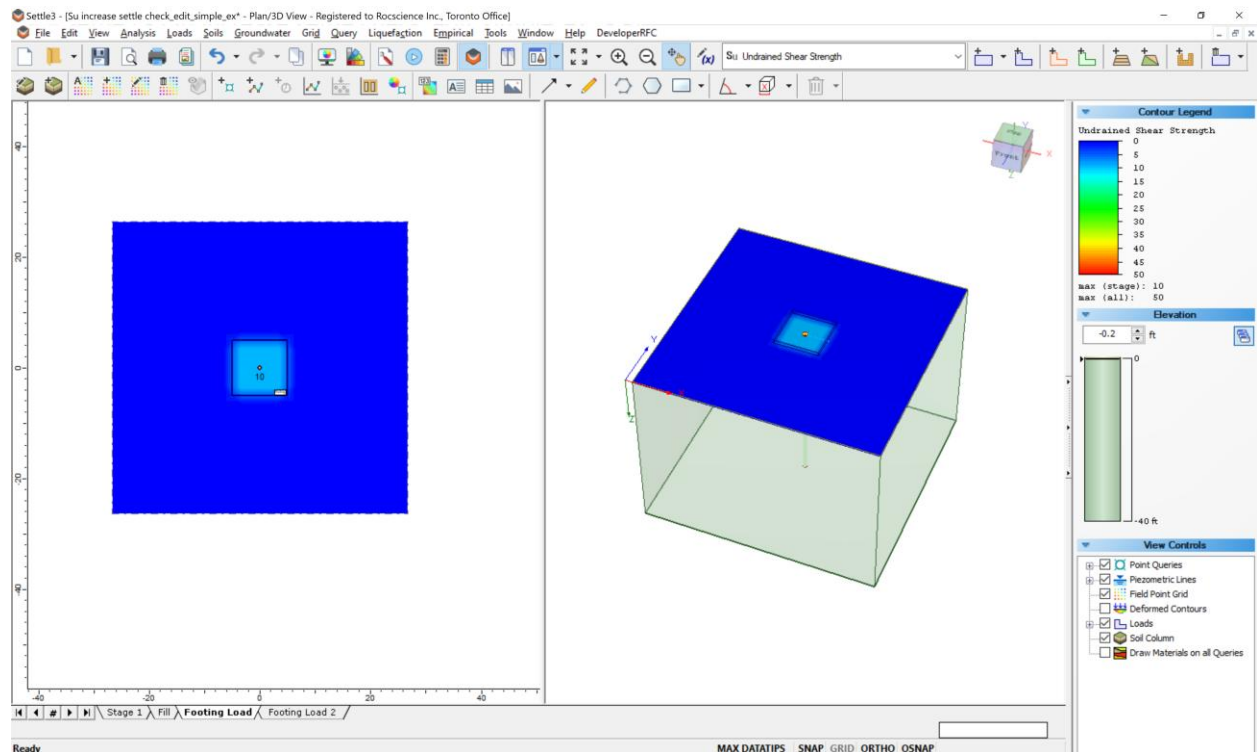
This example is simplified to demonstrate that undrained shear strength to show only the vertical consolidation stress when these parameters are used.

For the example provided, we'll create multiple stages and ground water at surface level. The depth of soil profile will be 40 ft.

At the initial stages when the load is not applied, Settle3 will return the initial undrained shear strength (S_{u0}) which is the A parameter defined in the Undrained shear strength dialog. Thus, if you have A = 0 in the dialog, then Settle3 will return undrained shear strength of 0 for the initial stages without load.



Then, when the load of 10 ksf is applied, you'll see that the undrained shear strength also shows 10 ksf as shown below:



In Settle3, in each stage, the calculated pre-consolidation stress, P_c , is compared to the previous maximum P_c . If $P_c > P_{cmax}$ then the increased undrained shear strength is calculated as:

$$S_u = A + (S_{ui} - S_{u0,calc})$$

Note that this $S_{u0,calc}$ is the initial **calculated** undrained shear strength and is **not the same as the A** parameter that the user has defined in the initial shear strength equation.

For Stage 0, the initial calculated S_u value is:

$$S_{u0,calc} = \sigma'_{0} S(OCR_0)^m$$

Where σ'_{0} is the effective stress in Stage 0.

OCR_0 is the in-situ OCR value in stage 0 (based on user-input).

And the current stage S_{ui}

$$S_{ui} = A + \sigma'_{vc} S(OCR)^m$$

Where $\sigma'_{vc} = \sigma'_{0} + \sigma_l - u_{et}$ (initial effective stress + current loading stress – current excess pore pressure).

$$OCR = \frac{\sigma'_p}{\sigma'_{vc}} = \frac{\sigma'_0 OCR_0}{\sigma'_{vc}}$$

So with the difference in the initial calculated undrained shear strength to the current undrained shear strength calculation becomes:

$$Su = A + ((A + \sigma'_{vc} S(OCR)^m) - \sigma'_0 S(OCR_0)^m)$$

Where $A = 0$, $m = 0$, $S = 1$ in our example. This leads to:

$$Su = 0 + ((0 + \sigma'_{vc} S) - \sigma'_0 S)$$

$$Su = ((\sigma'_{vc}) - \sigma'_0)$$

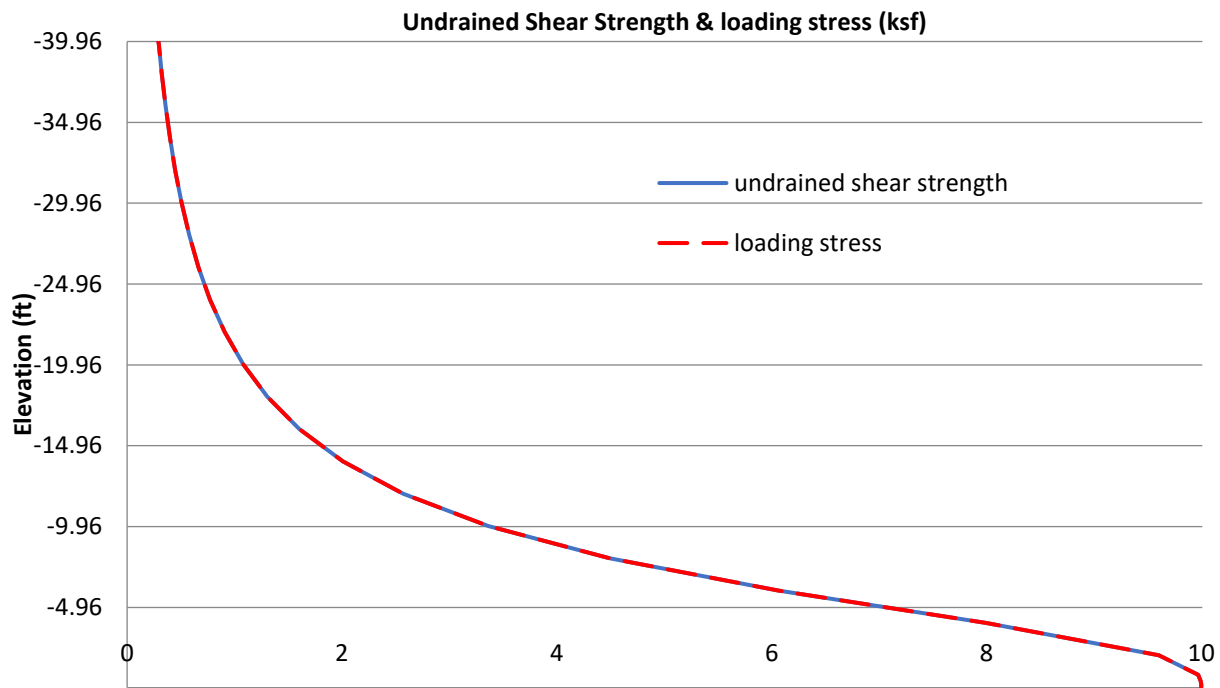
$$Su = (\sigma'_0 + \sigma_l - u_{et}) - \sigma'_0$$

Where there is no excess pore water pressure, so $u_{et} = 0$. This leads to

$$Su = (\sigma'_0 + \sigma_l - 0) - \sigma'_0$$

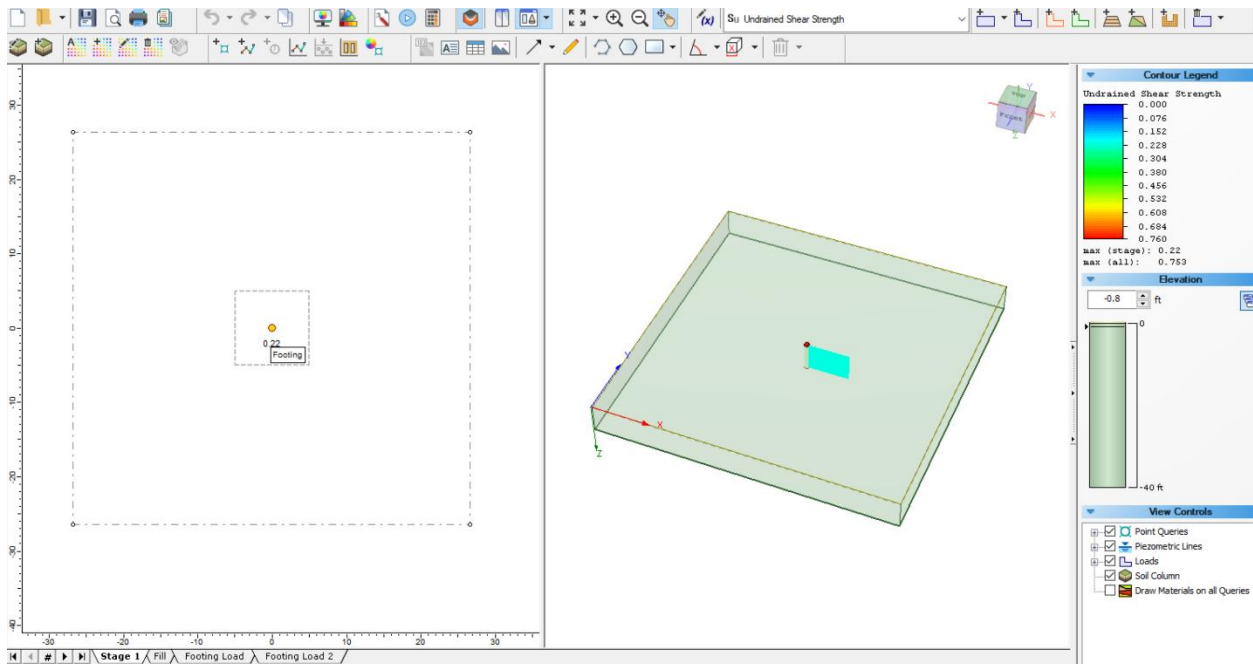
$$Su = \sigma_l$$

The undrained shear strength equals to the loading stress for this specific example and you can see that those two yield equivalent result underneath the load for 10ksf load as defined in the query line:



Case 2) $A = 0.22$, $S = 1$, $m = 0.8$.

For the same model, if you apply the coefficient value of $A = 0.22$, then the model will show the initial undrained shear strength shown in first stage, which has no load:



With the applied A coefficient to the calculation with different m value, then the undrained shear strength at the top of the query point at loading stress now changes compared to the case1.

Now this S_u value is calculated with the parameters $A = 0.22$, $S = 1$, $m = 0.8$. Note that for each stage, the P_c is calculated and then compares the initial calculated undrained shear strength with the initial effective stress to the current stage calculation and finds the difference of the two to yield the undrained shear strength.

$$S_u = A + (S_{ui} - S_{u0,calc})$$

Additional note

From the model, we have demonstrated how each parameter in the undrained shear strength equation changes the results using a simple example. There is additional option in the undrained shear strength dialog to use constant S_u in install stage. An “initial” stage other than Stage 0 can also be specified, as a global setting for all materials, and a “constant S_u in initial stage” can be selected on a per material basis. For more details on this, you can check our theory documentation for more details.

There’s also “A Advanced Option” which allows users to define datum dependency with three options: Bottom, Range of change, and Rate of change with Cutoff. This allows users to define A parameter with datum dependency with respect to the user-inputs from one of the following options.

Undrained Shear Strength

A: 0.22 kips/ft2

S: 1

m: 0.8

$$S_u = A + \sigma'_{vc} S (OCR)^m$$

☒ A Advanced Options

Rate of Change

Bottom

Rate of Change

Rate of Change with Cut off

Cut off: 0.0

☐ Constant S_u in install stage

Initial Stage: Stage 1

OK Cancel

Note that the purpose of this documentation was to demonstrate how the parameters are used to calculate the results. This feature can be carried out in more complex models to illustrate the undrained shear strength calculations with multiple stages in Settle3. We encourage users to be familiar with the equations provided in the documentation and refer to the original reference provided below. ■

Reference

Ladd, C. (1991). "Stability Evaluation during Staged Construction." J. Geotech. Engrg., 10.1061/(ASCE)0733-9410(1991)117:4(540), 540-615. (The Twenty-Second Karl Terzaghi Lecture)