CC-TEST, CLAY CUTTING TEST

P. Hedborg[1]

KEYWORDS

Clay-Cutting, CC-Test, Shear strength, Test rate/cutting rate

ABSTRACT

With nearly twenty-five years of experience, I have specialized in geotechnical laboratory testing, using a range of analyses to improve my understanding of soil behavior. These tests include basic methodologies such as the fall cone test, as well as advanced methodologies like triaxial testing. Enhanced understanding of soil behavior is obtained through conducting a larger number of tests on soil samples and compare with different testing methodologies. The result gives a more solid and accurate understanding.

The fall cone test is primarily an index test, measuring cone penetration within a limited part of the soil sample. Usually, the fall cone test is performed on a five centimeter sample per meter, representing a small part of the entire soil profile.

More advanced tests such as direct shear tests can be done, but also here, only a small part of the full sample is tested.

The soil samples often have significant natural variation and the different laboratory test methods do not always give consistent results. In this context the idea of measuring a more extensive sample started to grow.

It was important to see how the shear strength varied with depth within the sample. One way of doing that was to vertically slice the sample and visually observe the changes. Another way was to measure the resistance while cutting the sample.

From the beginning a load frame with constant rate was used and a manual cutter was fixed to a force transducer. The force was measured during the procedure of cutting through the sample. The result gave a good understanding of how the shear strength varied with depth. This simple arrangement was the first prototype of a new laboratory equipment and I call the test, The Clay-Cutting-Test (CC-Test).

The CC-Test has evolved over time since the first test was performed. The equipment is a simple tool, and the cutter can be recognized as the tool that is

[1] ÅF-Infrastructure AB

used to trim soil samples in other geotechnical laboratory tests. An experienced laboratory engineer can "feel" the shear strength when cutting the clay. The cutter is pressed by hand through the sample and cuts the clay with a metallic thread.

The possibility of gathering a lot of data in a short period of time has been important in develop the CC-Test. The test measures the force over 1000 times per minute. It only takes two minutes to analyze 10 centimeters of a soil sample which made it possible to in several ways validate the method. Thread parameters with focus on material, dimensions, tension, and test rate have been studied to obtain the best results.

Figure 1 CC-Test Equipment and, handheld Cutter.

1. SHEAR STRENGTH OF SOIL

The strength of soil depends mainly on its composition and geological history of deposition and loading. Over time, good empirical knowledge has been created about how the strength in clay varies with plasticity, preconsolidation pressure and degree of overconsolidation, as well as in organic soil with content and type of organic material.[1]

Using the CC-Test to analyze various empirical relations in soil

Initially, tests were performed to verify the method and to see how the CC-Test can be used. Several types of soil have been tested. The resistance of the wire varies as it passes through different soil layers. By combining the results from the CC-Test with a photo of the sliced soil surface it is possible to see how the resistance varies through the sample, which strengthens the method. No major study has been done to analyze this more systematically, but there is a lot of information that potentially can be used to classify the soil.

No empirical correlations have been used to correct the methodology yet, the measurements are completely uncorrected. Focus has been to analyze the shear strength and see how the CC-Test compares with other test types.

Suggested symbols for the CC-Test

CC-Test = Clay Cutter Test

F_{CC} = Wire Force(kN)

A_{cc} = Wire mantle area in the soil(m^2)

L_W = Wire length in the soil(mm).

D_W = Wire diameter(mm)

τ_{CC} = Uncorrected shear strength (kPa)

Equation 1. $A_{cc} = \pi \, x \, D_W x \, L_W$

Equation 2. $\tau_{CC} = \dfrac{Fcc}{0{,}5 \; x \; Acc}$

2. QUESTIONS

The questions that needed further attention were:

- Test rate/cutting rate
- Repeatability
- Wire parameters (diameter, tension, material)
- Sample height

Test rate/ cutting rate

To study the effect of the cutting rate homogeneous clay samples from the Gothenburg area with density between 1.55-1.58 t/m^2 and with water content between 75-85% was used.

Two different test rates were initially utilized to see if the rate had some effect on the force on the tread. In the first sequence of tests, the rate of 2 mm/min and 5 mm/min were used and clay from three different depths were studied.

These results were compared to see how the force was affected by the cutting rate, see Figure 2. Results from the fall cone test were also used as a reference.

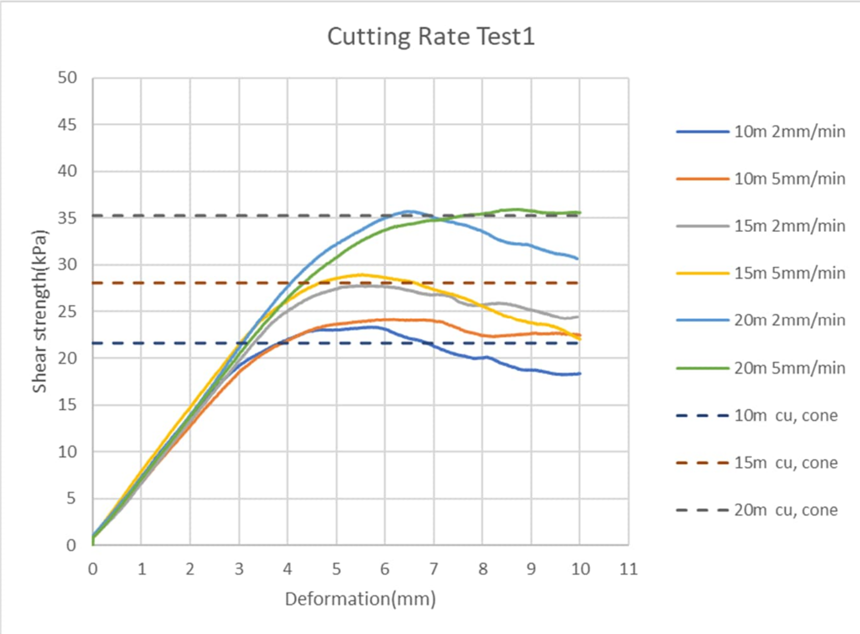

Figure 2 Tests with different cutting rates.

These first series did not indicate that the velocity significantly affected the result. To select a standard velocity more tests were needed to be done, and with a greater span of the soil strength.

Initially the CC-Test was calibrated against the fall cone test. Around twenty parallel tests were performed, and a conversion factor was calculated from the tread resistant load. This made it possible to compare the test from the start and collect data by testing the methodology in different soils.

The conversion factor was then compared with the wire dimensions and what fitted best were the halves mantle area of the wire. This factor was close to the conversion factor from the cone and worked well for other wire diameters. Therefore, the equation 2, was used for from this point.

When tests with considerably lower test rate was performed, the test showed higher shear strength.

The soil sample that was tested had a low shear strength and the cutting area showed significant signs of closing after the tread had passed through, see Figure 4.

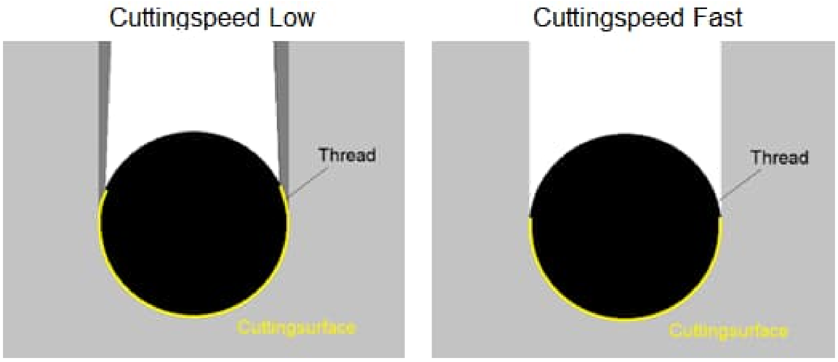

Figure 3 Contact area between soil and thread depending on the test rate.

Repeatability

To study and validate the repeatability of the CC-Test, a homogeneous clay used for pottery was tested. Cubic samples were cut out and several tests were done to see how repeatable the test could be. During the whole procedure the same test rate were used,

The same clay was then used with different cutting rates to see how the test rate affected the shear strength. The conclusion was that it was better to use a higher rate since the soil seemed to reach a certain limit where the contact area between the wire and the soil did not affect the shear strength, see Figure 4.

At this point a test rate of 40mm/min was chosen for further testing and analysis but more tests with different cutting rates in different soils needs to be done to see if it has any effects on the shear strength.

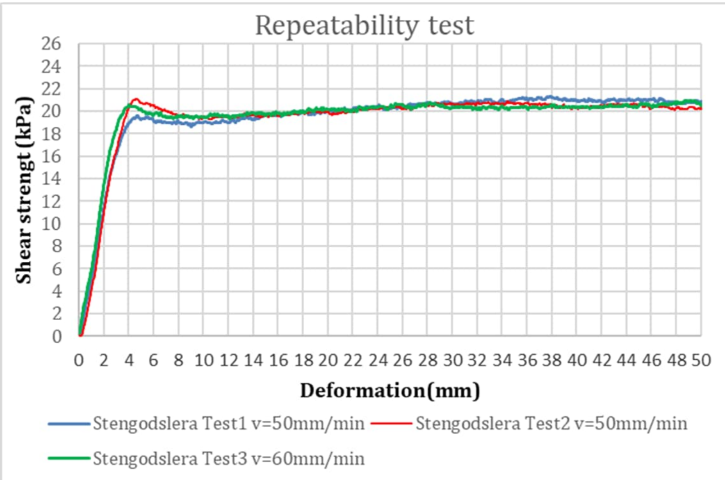

Figure 4 Two tests made on identical samples with different cutting rates

Wire parameters

To make a solid and robust equipment the tool had to have a stiff design and a mounting mechanism that enabled changing the thread and get the same tension in the thread every time. The diameter and the tension in the tread have been important parameters to test and see how it affected the output of the test.

The induced force depends on both the cutting length in the soil and the cutting surface on the tread. Therefore, the tread had to be thin and with a high strength, and stiff enough so the length of the thread was constant during the test.

Threads are used in other purposes such as fishing. any of these treads has high strength but one problem with using these treads is the tightening procedure where the roundness easily gets affected. This fact contact area on the wire and soil.

Metallic threads with different diameters have also been studied. The conclusion was that a diameter of 0,20-0,28 mm functioned well for most soil samples. To be able to tighten the tread to the same tension every time a special torque wrench was used.

Sample Height

In an early period of testing a small sample was used, a height of 20 mm was a good height for many tests. The standard sample tube in Sweden is a 170 mm long tube. For every sample depth there is one upper, one middle and one lower tube.

The CC-Test is a very time efficient test compared to other methodologies, and it generates many measurements during the cutting procedure through the sample. A cutting rate of 2-5 mm/min and the fact that the thread only needs to cut 2-5 mm into the sample before reaching a consistent value, made it possible to do many tests in a short period of time. Different parameters could be tested to see if it affected the result of the evaluated shear strength.

The very first CC-Test that were calculated from the conversion factor from the cone, reminded of a simple direct shear test, see Figure 5. The value obtained also correlated with the result from the direct shear test.

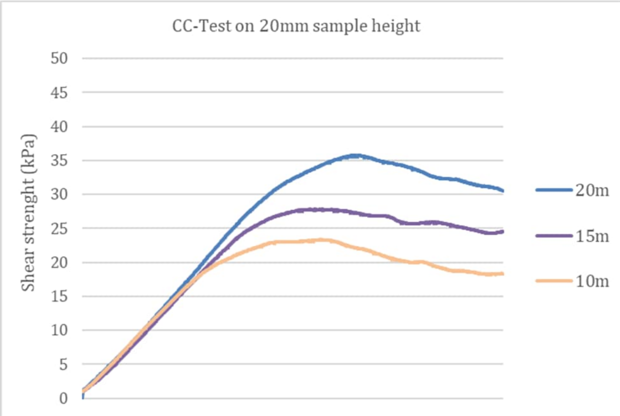

Figure 5 The firs result with small sample heights (20mm).

Initially the mantle area of the wire was not included in the preliminary evaluation of the shear strength. It was only the load that was measured from the CC-Test divided with the result from the fall cone test. This factor was then used to the rest of the tests to see how the value compared with the other sample depts, see Figure 6.

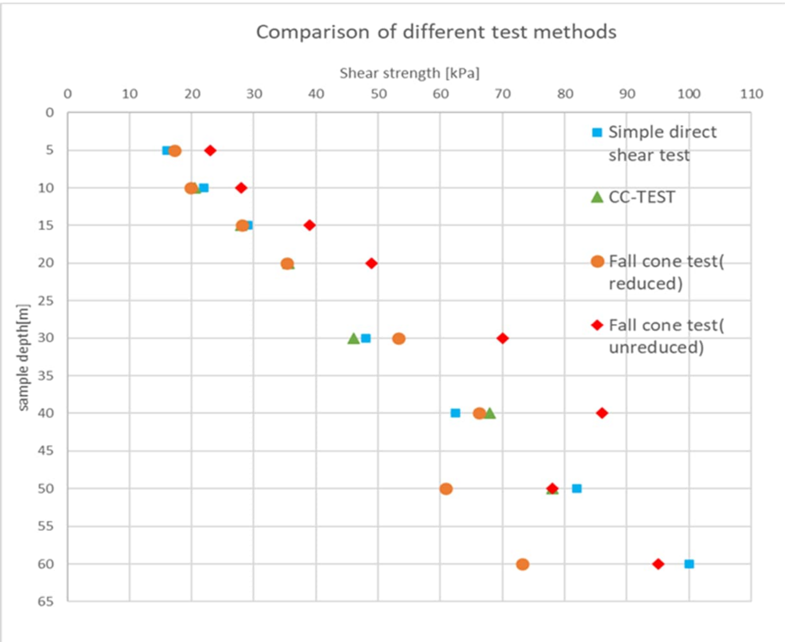

Figure 6 Comparison between different types of tests.

It is well known that the fall cone test is calibrated and representative to a depth of about 15 m in the western part of Sweden. The vane test often shows representative values down to a depth of 20 m. At greater depth the direct shear test usually is the most reliable methodology. The CC-Test seems to correlate well with the fall cone, the vane, and the direct shear test to a limited depth. As seen in Figure 6. the CC-Test and the direct simple shear test also correlate with depth and it seems like the unreduced fall cone test fits the trend with depth as well.

After the first test on small sample heights, many more tests were done on different soils. The question was what the thread could measure? Were there any limitations? By performing many comparative tests with both fall cone test, direct shear tests and triaxial tests more trust to this new way of testing the soil was gained. The aim was to adjust the cutting rate, the wire diameter, and the wire material to get closer to the direct shear test, to trim in the CC-Test.

At this stage larger samples were introduced in the CC-Test development. The purpose was to see how the methodology could manage variation in the samples.

When the fall cone is used an analysis is done for every 2 cm layer and the cone penetration length can vary more than one millimeter. That affects the calculation for the shear strength. To study such a small sample will give a very specific value that in many cases does not represent the variation in the whole soil profile. With the CC-Test and more extensive sample height the variation could be measured in a laboratory.

Verifying test

To verify the method, the CC-Test have been performed parallel and systematically with the fall cone test in more than 400 cases. By collecting three, 2 cm layers used from the fall cone procedure and run in the CC-Test equipment, data from the same sample can be compared with data from different methods. Shear strength from the CC-Test is illustrated with the reduced and un-reduced shear strength from the fall cone, see Figure 7. The comparison shows that the minimum and maximum shear strength from the CC-Test varies between reduced and unreduced shear strength from the fall cone test. This trend can be seen to a certain depth.

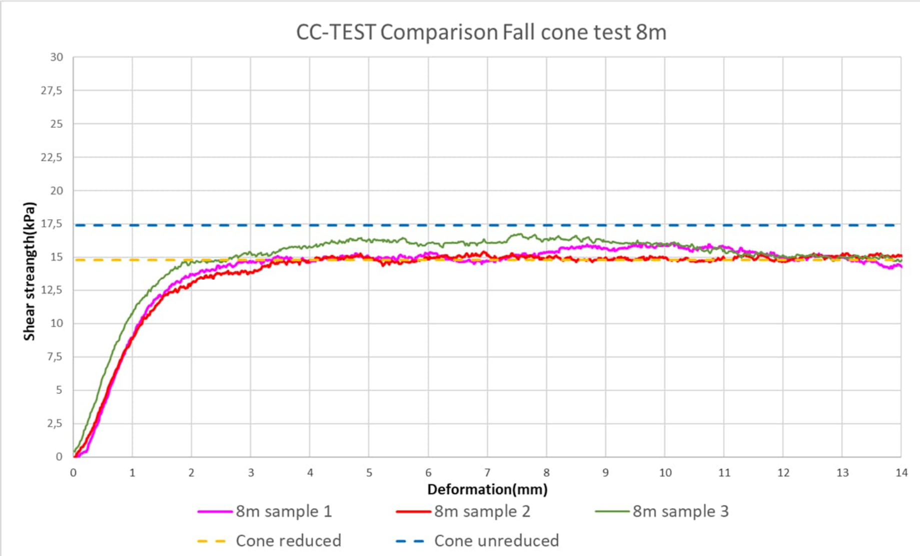

Figure 7 Comparison test with fall cone test.

3. CC-TEST WITH DIFFERENT PURPOSES

CC-Test to measure soil variation

A sample was taken out directly from the sample tube and the test length was chosen to 10 cm. The first step in this test procedure was to cut in the center of the sample through the hole sample length. After that the sample was divided into pieces of 2 cm horizontal and each sample was then tested again with a rotation of 90 degrees. The rotation was done to get an undisturbed part of the sample to test again, see Figure 8

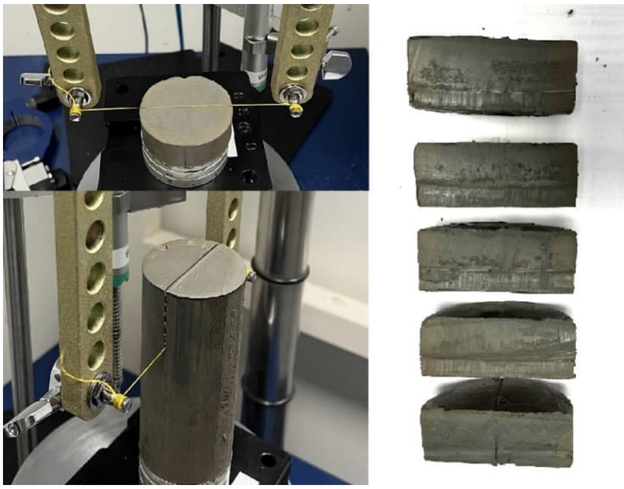

Figure 8 Test in different directions.

The result from the double test showed that the full height test did not affect the test from the five divided parts that was made on the same sample. All measurements from the test were plotted in the same graph, see Figure 9. and the cut in the full height test fitted perfectly with the small sample tests.

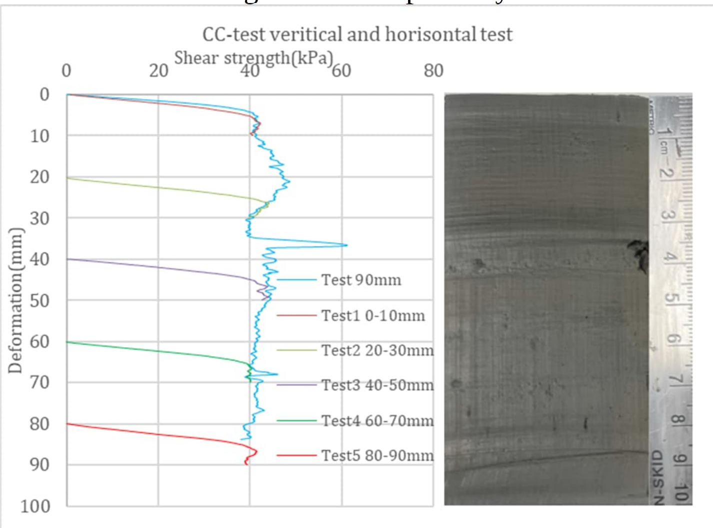

Figure 9 visual fit between a full height sample and five small samples performed with 90 degrees rotation.

CC-Test to measure variation depending on direction in the soil

Tests has been done on the same sample, but in different directions, see Figure 10. to study the repeatability of the test and to see if there are any differences of the strength in different directions. The result showed that the test could be made in many directions of the sample and almost get the same result and without disturbing the sample.

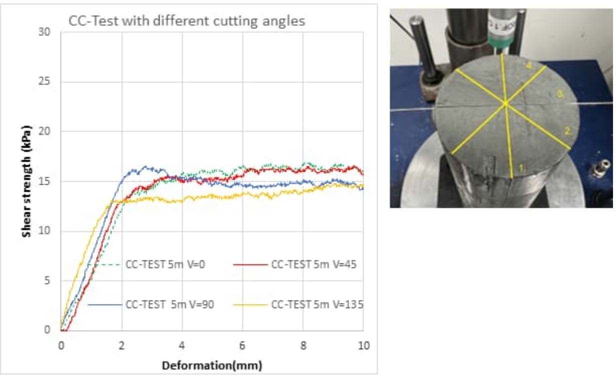

Figure 10 Validation of the results in different directions.

CC-Test on a sulfide clay

To investigate the possibility to measure variations depending on the sulfide content CC-Tests were done on samples from the north of Sweden. In the soil a substantial variation could be seen and the shear strength from the fall cone test showed different values depending on which sample tube that was used on the same depth (upper, middle, or lower tub). To get a better trend towards the depth some simple direct shear tests were performed. When they were summarized in the graph together with the fall cone test it still showed an extensive variation and it was difficult to explain why there were such a spread between the different methods.

Therefore, some CC-Tests were done to analyze the soil and see if the variation could be measured. The results showed that it was a great variation through the hole section. The darker sulfide layers gave a higher shear strength, see Figure 11.

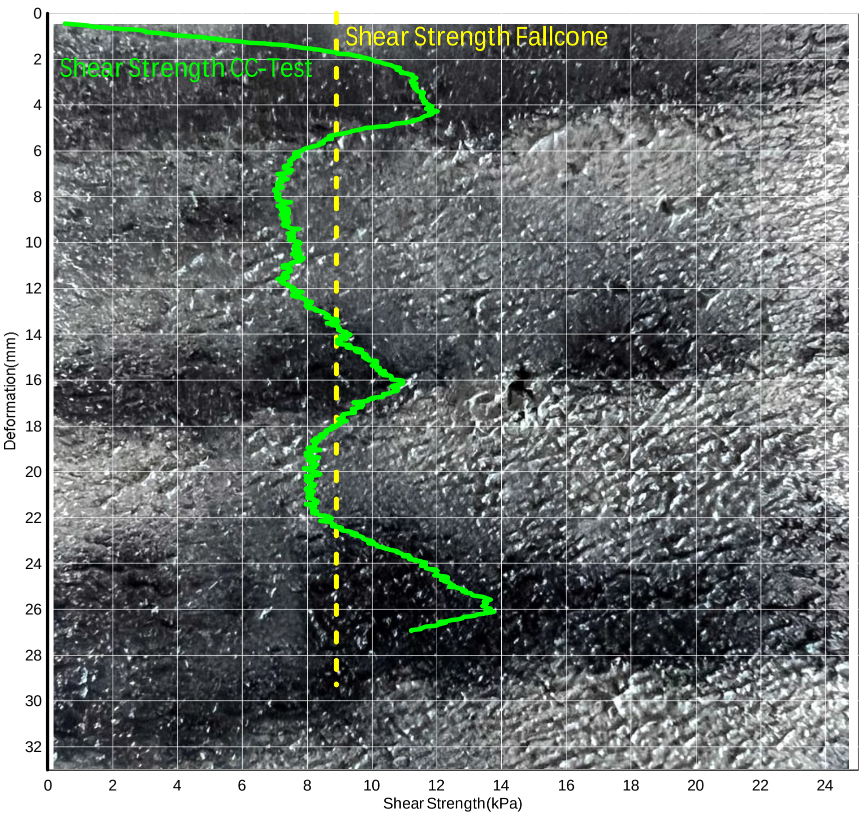

Figure 11 Soil profile with shear strength variation.

4. CONCLUSIONS

The combination of measuring the shear strength in the soil and document the cutting surface with a photo gets a better understanding of the soil. Many different analyses have been performed in this study since the methodology is simple, not very time consuming. The fact that the CC-Test is a partly nondestructive test gives the possibility to get measurements in different directions. Hopefully the CC-Test will be standardized in the future. What need to be done to validate the methodology is something that has to be further discussed.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to all those who helped me complete this project successfully.

First and foremost, I would like to thank my Employer AFRY and my colleagues who have been positive and interested about the development of this project. Especially to my close colleague in the laboratory, Hanna Karlström. She has been very helpful in discussions and her curiosity has encouraged me in the development of the CC-Test.

And thank to my close colleague Fanny Molander that have been very helpful together with Hanna Karlström with the report and discussions.

I also want to thank my colleague Henrik Åslund for all the discussions regarding thread variants and his shown interest in the development.

I would also like to extend my thanks to my mentor Göran Sällfors. Especially with his feedback and expertise regarding the method.

Finally, I would like to thank my family who motivated me and boosted my morale when I was stressed. Without their unconditional love and support this project would not have been possibly.

[1] Shear strength - evaluation in cohesive soil. Information 3.
SWEDISH GEOTECHNICAL INSTITUTE