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Kristina Thomassen

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Department of Civil Engineering
Division of Structures, Materials and Geotechnics

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Test Procedure for Axially Loaded Piles in Sand

by

Kristina Thomassen

October 2015

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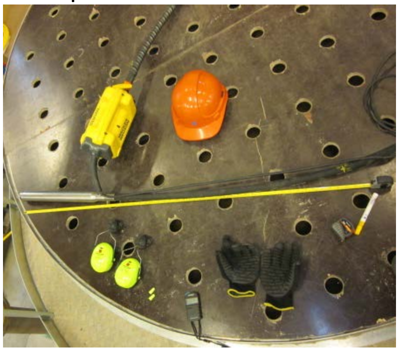
Contents

1 Objective

The test procedure described in the following is used when examining the effects of static or cyclic loading on the skin friction of an axially loaded pile in dense sand. The pile specimen is only loaded in tension to avoid any contribution from the base resistance. The pile dimensions are chosen to resemble full scale dimension of piles used in offshore pile foundations today. In this report is given a detailed description of the soil preparation and pile installation procedures as well data acquisition methods. Thomassen (2015a) gives a detailed description of the test setup and used equipment while safety instructions are given by (Vaitkunaite, et al. 2015).

2 Safety Equipment

Safety shoes	-	Should be worn all the time
Helmet	-	Should be worn all the time except when seated at the computer
Safety sling	-	Should be worn when standing on the sand box edge or the footbridges across the sand box
Earmuffs	-	Should be worn when vibrating
Vibration gloves	-	Should be worn when vibrating
Gloves	-	Could be worn as protection against splinters or the like
Knee protections	-	Could be worn



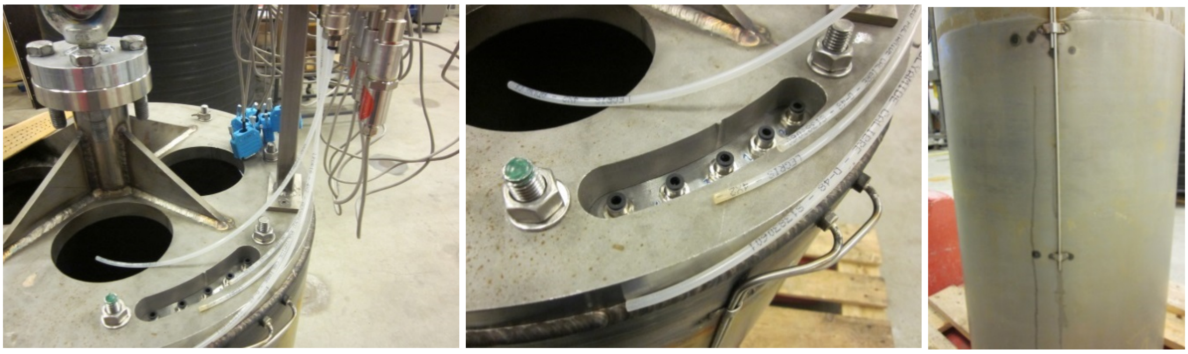
3 Pile Installation

The pile is installed in the sand prior to soil preparation to avoid any installation effects on the test results.

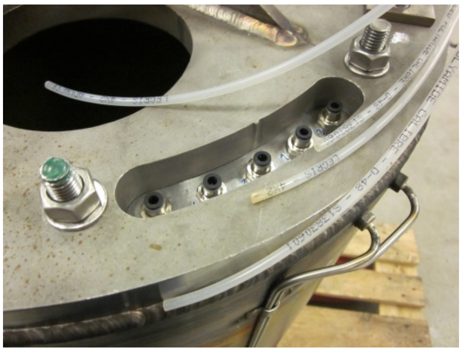
3.1 Preparation of the Pore Pressure Transducers

The pipes along the pile shaft which is connected to the pore pressure transducers should be blow free of sand.

1) Disconnect the pore pressure transducers from the steel pipes running along the pile shaft.



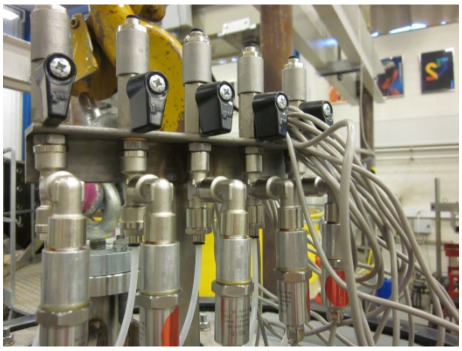
2) Blow through the pipes with a compressor.

3) The hoses from the pore pressure transducers are hereafter mounted again. Make sure that the hoses are connected to the correct pipes and pore pressure transducers by following the numbering.

The pore pressure transducers are saturated.

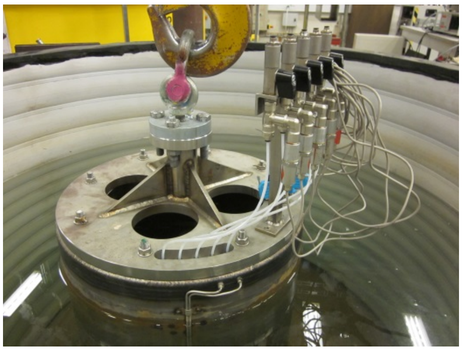
1. Open the valves above the pore pressure transducers to enable free water flow through the pipes.

2. Lift the pile by use of the ceiling crane and brush of any sand from previous tests.

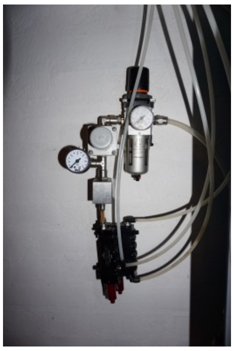
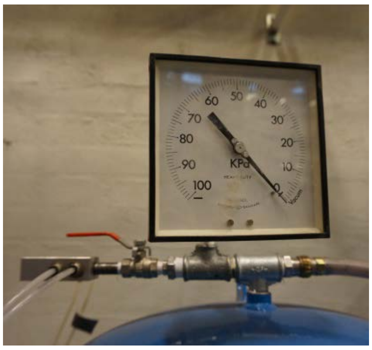


3. Immerse the pile in the water reservoir standing next to the sand box until it hangs 1–2 cm above the bottom.

4. Turn on the vacuum pump by opening the valve on the wall next to the blue tank and turn the knob on the regulator on the side of the blue tank.



5. Use a three-legged quick-coupling to make a closed circuit of three of the hoses connected to the vacuum pump. The remaining hose is connected to a smaller diameter hose, with another quick-coupling.



6. Suck water up to the pore pressure transducers by means of the vacuum pump. Open and close the valves on the hose below the pore pressure transducers a few times while suction is applied until no air bubbles are trapped inside the valves.

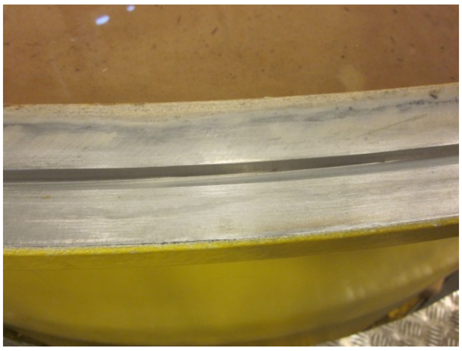
7. Close the valve above the pore pressure transducers.

8. Check that the water does not sink in the hose underneath the pore pressure transducers after the valves are closed. If it does, one of the connections is not tight and should be tightened or repaired.

3.2 Loosening the Sand

If Aluminium frame 1 is not clamped to the edge of the sand box, the succeeding procedure is followed.

1. The groove at the edge of the sand box is cleaned with paper and compressor.

2. The thick rubber ring is placed in the groove. The rubber should be clean and dry before doing so.

3. Aluminium frame 1 is placed on the edge of the sand box so that the numbering on the frame and the sand box matches.




4. The frame is clamped to the edge to make the connection water tight with at least eight clamps. First put clamps at the four numbered positions of aluminium frame 1. Then put one clamp between each pair of the first clamps. Check that the first for clamps still fits tightly.

To enable pile installation and following vibration of the sand, the sand is loosened by a hydraulic gradient of $i = 0.9$. This value of the gradient ensures that the soil is loosened enough without creating water channels in the sand. The gradient is applied for at least five minutes and until the water level is 5-8 cm above the soil surface. The reason for raising the water level above the soil surface is to avoid air flowing into the sand during vibration. A gradient of 0.9 is obtained by letting water in trough the bottom of the sand box and choosing the correct difference in water head, Δh, compared to the thickness of the sand layer, $H = 1.2$ m.

$$i = \frac{\Delta h}{H} \Leftrightarrow 0.9 = \frac{\Delta h}{1.2\ m} \Leftrightarrow \Delta h = 1.08\ m$$

Applying the gradient.

1. Before applying the gradient it is ensured that the water tank is filled. If necessary, water is lead into the tank by opening the valve. Make sure to close the valve leading water into the sand box before filling the water tank. When the water tank is full, close the valve letting water into it.



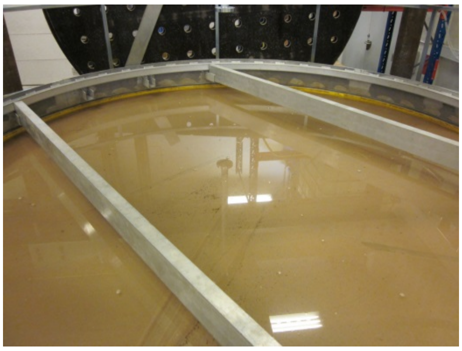
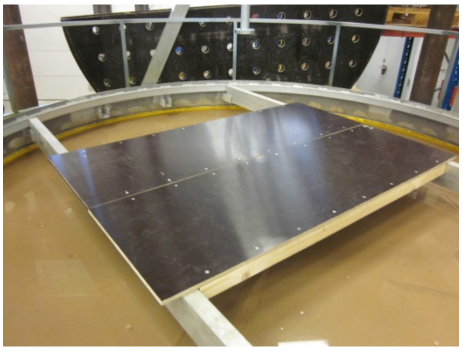
2. The valve leading water into the sand box is opened. The difference in pressure head is monitored in the ascension pipe. The correct level is marked by a piece of yellow and black tape. The pressure head is controlled by adjusting the flow through the valve.

3. Close the valve when the wanted water level in the sand box is reached.


3.3 Connection of the Pile to Hydraulic Cylinder 1

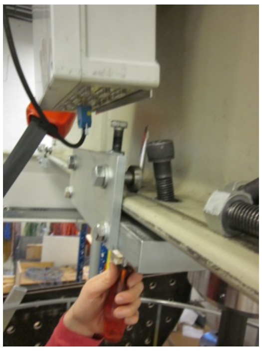
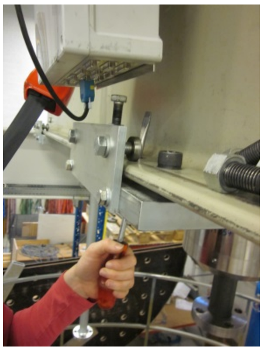
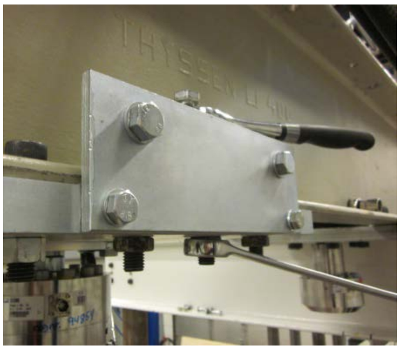
Workspace is created.

1. The two short aluminium bars are placed according to the numbering of the sockets on aluminium frame 1. The footbridges are placed between the aluminium bars in the middle of the sand box.

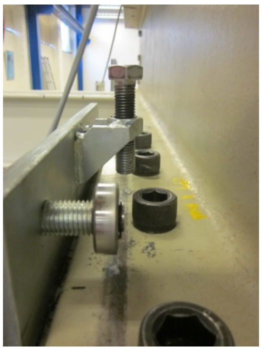



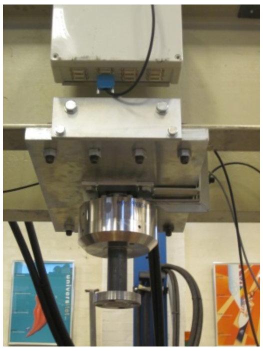
Positioning hydraulic cylinder 1.

1. The rack of hydraulic cylinder 1 is fastened in the middle position of the load beam with the eight bolts. If the holes for the bolts do not fit entirely, the cylinder is moved slightly sideways by means of a screwdriver or something like it. The four corner bolts are tightened little by little in turn till the flanges of the rack and the loading beam are tight together. Hereafter, the last four bolts are tightened and all bolts are checked.

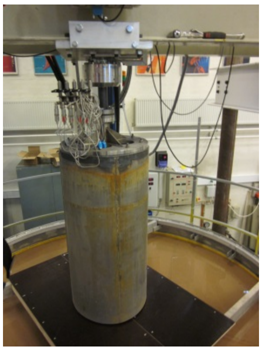
2. The screws in the middle of the rack are lowered till they touch the load beam this will ease the release of the bolts later on.



Connecting the pile to hydraulic cylinder 1

1. The pile is lifted from the water reservoir with crane and placed on the footbridges.

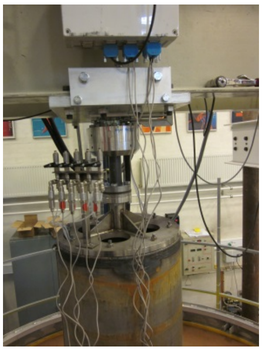



2. The pile is disconnected from the crane and pushed underneath the transition piece 2 to hydraulic cylinder 1 so that the holes in the two match.
3. The pile is connected to the transition piece with four bolts, and lifted a little bit with hydraulic cylinder 1 from the footbridges. Make sure that two of the holes in the pile flange are aligned with

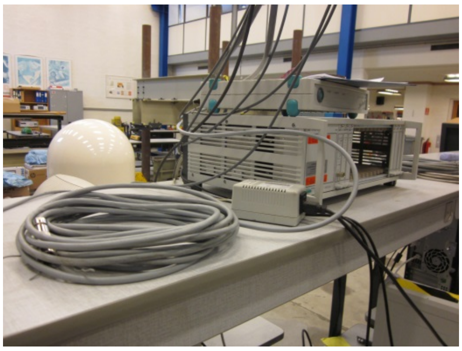
the load beam so that CPTs can be conducted inside the pile after installation and vibration without moving the load beam.



4. The pore pressure transducers are connected to the box hanging on the load beam which is connected to the MGCplus.

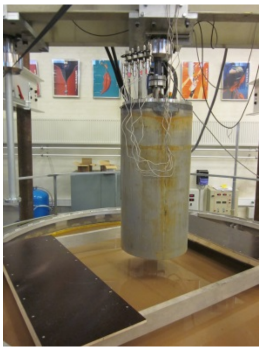
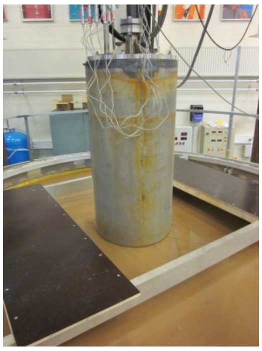



5. The load cell is connected to Spider 8 to enable monitoring the load during installation.




6. A displacement transducer, permanently connected to Spider 8, is fixed to hydraulic cylinder 1 and measures its movements.


7. The footbridges are moved from underneath the pile to the sides of it and the pile is lowered until it touches the sand surface.

3.4 Installation

Turn on the computer connected to Spider 8 and MGCplus and start up Catman.

1. (Detailed description of procedure in Catman)
2. Check that the pore pressure transducers are still saturated and note in the log book if some of them are not.
3. Check that the pore pressure transducers, the load cell and the displacement transducers are measuring correctly.
4. Reset the measurements.

Installing the pile.

1. Set the installation rate to 6 mm/s by turning the black knob on the switchboard.

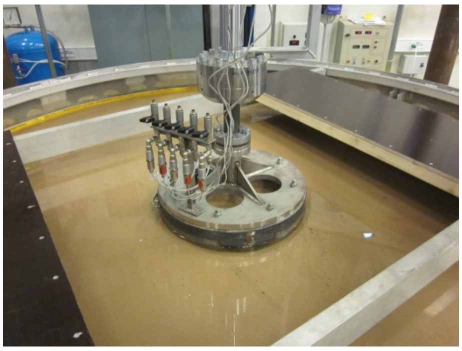
   

2. The black knob on the controller is positioned in the middle or upper position which will introduce the displacement rate set on the switchboard. If it is positioned in the lower position, the displacement rate will be 6.18 mm/s (maximum). The red button is pressed to stop the cylinder moving. The cylinder will stop automatically when the cylinder it reaches its outmost.

3. The installation is started with hydraulic cylinder 1 and at the same time Catman recordings are started.

4. The pile plugs at the last part of the installation and the hydraulics cannot provide the power necessary to push the pile further into the sand; instead it begins to punch the pile into the sand. To avoid this, pull the pile out by approximately 1 cm and then continue to push the pile down.
5. The installation is stopped when the hydraulic piston is in its outmost position which corresponds to an installation depth of approximately 0.98 m.



6. Catman is stopped and the measurements saved.
7. The load cell is disconnected while the pore pressure transducers stays connected.

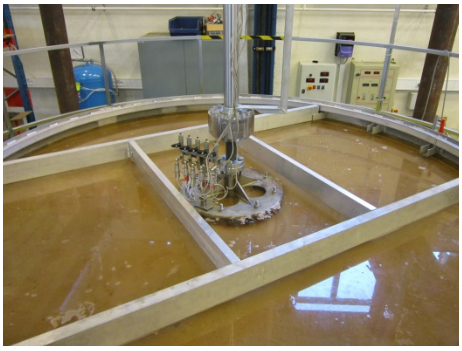
4 Preparation of the Sand

The sand in the sand box is prepared before each test to insure a high density of the sand ($D_r \approx 85\%$). Moreover, the preparation ensures that the density is similar in all the conducted tests. The procedure is to vibrate the sand with a rod vibrator, and hereafter checking the density by CPTs several places in the sand box.

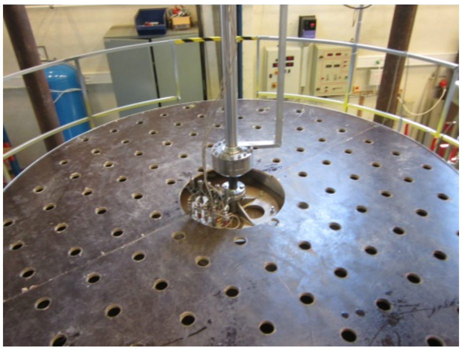
4.1 Vibrating the Sand

Mounting the vibration plate.

1. Two small aluminium bars are placed in the sockets on the two aluminium bars that are already there.



2. The vibration plates in the stand next to the sand box are placed on the beams so that the straight sides are parallel to the long aluminium bars. Check, that no holes are blocked by the aluminium bars.

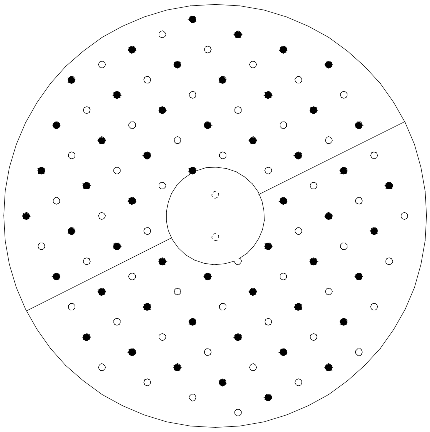
Safety procedure.

1. Vibration is done with a rod vibrator through the holes in the vibration plates. Safety shoes, helmet, earmuffs/earplugs, and vibration gloves is worn. It is important to wear the correct size of gloves as it can give friction wounds to wear too small or too large gloves. If seated while vibrating it is not necessary to wear the safety sling.

2. Vibration is only allowed for one hour at a time, after that a one hour break is compulsory, due to the risk of getting vibration white fingers.

Vibration procedure:

1. Before conducting a test with the 1 m long pile, vibration is done in every second hole of the plates. To vibrate 110 cm down, a powerful rod vibrator with an effect radius of 60 mm is used. Before one test, the vibration holes marked by solid circles in the principle sketch are vibrated and before the next test, the holes marked by non-solid circles are vibrated and so on for the following tests. This is done just to ensure a more homogeneous compaction of the soil by not vibrating in the same holes every time.



2. The sand inside the pile is also vibrated. The sand is vibrated at the two positions inside the pile marked by dashed circles in the principle sketch. These two positions should not be aligned with the load beam, because CPTs should be conducted after vibration and not in a vibration hole and CPTs can only be conducted in line with the load beam.
3. The vibrator is gently pushed into the sand until the yellow mark on the vibrator hose is at the same level as the vibration plate. This corresponds to a vibration depth of 1.10 m and should take approximately 1 min.



4. The vibrator is pulled gently out of the sand in approximately 1 min.

4.2 After Vibration

Before conducting CPTs the water level is lowered to approximately 1 cm above the soil surface.

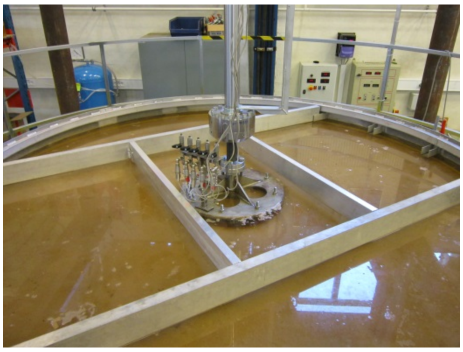
1. This can be done in two ways.
    a. The first way is to place the end of the hose attached to the out-valve in the drain. The out-valve is then opened and the water flows out through the bottom of the sand box. This is a rather slow method (approximately 30 min) and courses a downward gradient in the sand, which may lead to a small increase in the soil compaction.

b. The other method is to lead the water out from the top of the sand box. Make sure that the out-valve is closed and detach it from the pipe. Place one end of the hose in the drain and the other in the water over the soil surface. A vacuum cleaner can be used to get the water flowing to the drain. Make sure that the sand is not sucked into the hose and out in the drain. This method lowers the water level in approximately 10 min and does not influence the compaction of the soil.

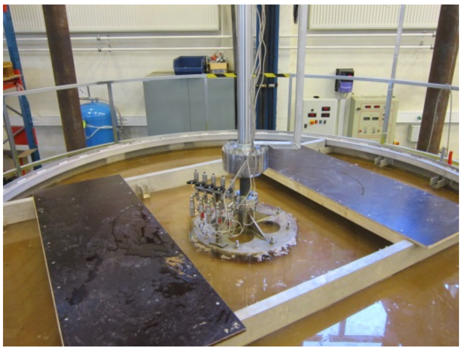
2. Afterwards, the hose is reattached to the out-valve and rolled together.

Preparing work platform:

1. The vibration plates are removed and placed in the stand mounted on the side of the sand box.

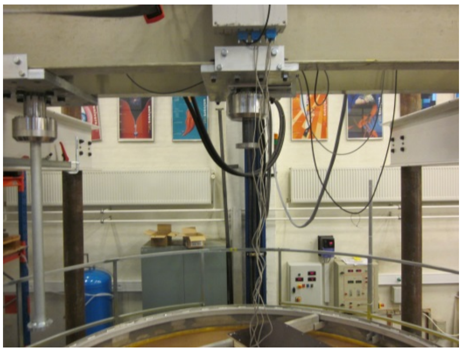
 

2. The two small aluminium bars are removed and the two footbridges are placed between the two remaining beams.

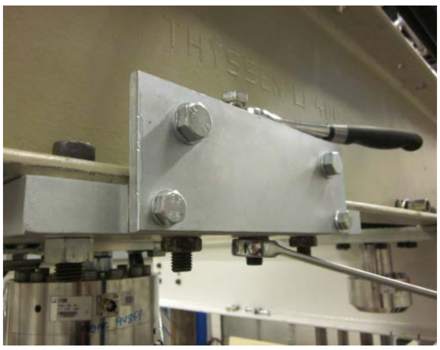
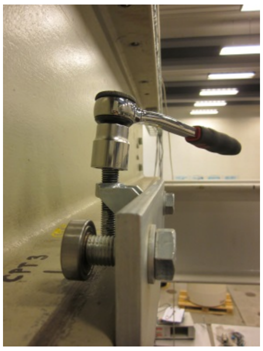


Hydraulic cylinder 1 is moved from the middle position to the right side of the load beam.

1. Hydraulic cylinder 1 is detached from the pile by removing the four bolts and the cylinder is raised to its uppermost position.

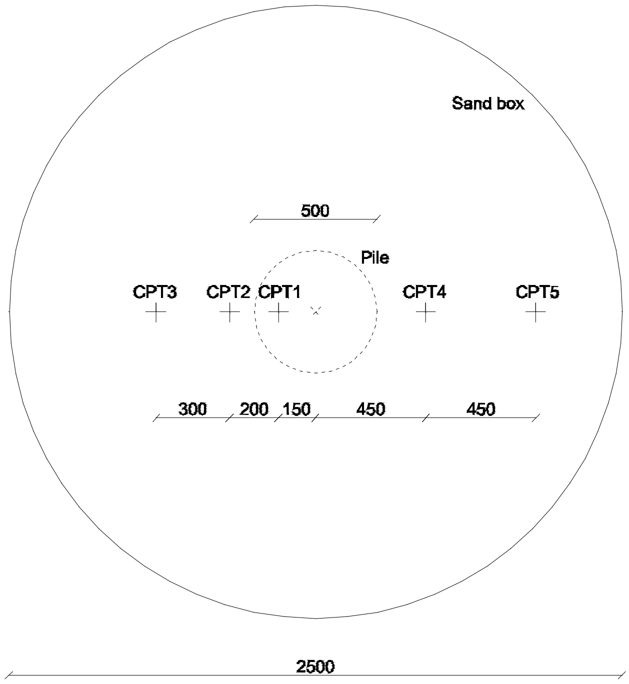


2. The eight bolts fastening hydraulic cylinder 1 to the load beam is loosened and removed, thereafter, the middle bolt on each side of the load beam is loosened with the ratchet spanner.

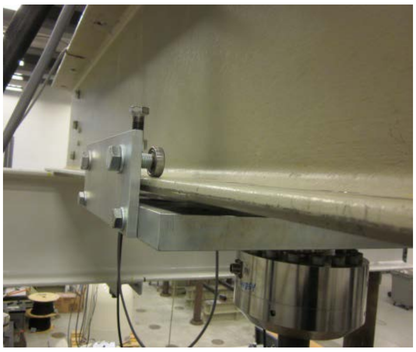
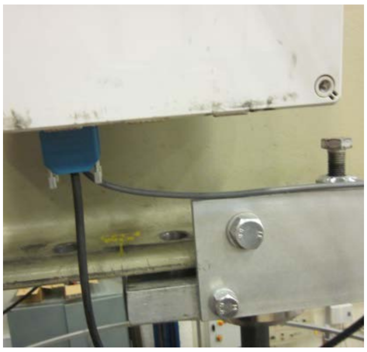
4.3 Conducting CPTs

CPTs are conducted five places in the sand box to validate that the sand is approximately homogeneous throughout the box.



Preparation before conducting the first CPT.

1. Move the rack holding hydraulic cylinder 1 to the first CPT position. The screws on each side of the rack holding hydraulic cylinder 1 is positioned above the “CPT 1 PILE” mark on the load beam flange. The screws are tightened with the racket spanner until the rack and the load beam flange is tight together and the rack cannot be moved.

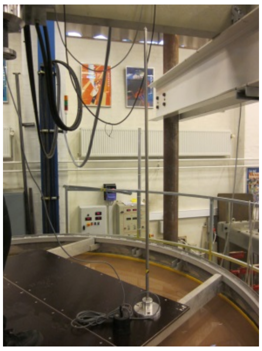







2. Remove transition piece 2 (to the right) from the load cell and insert transition piece 1 (to the left) instead.

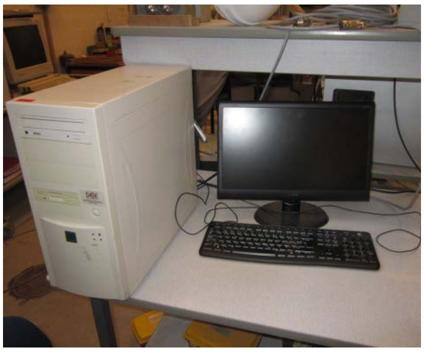
3. The CPT device is connected to the transition piece with two bolts.

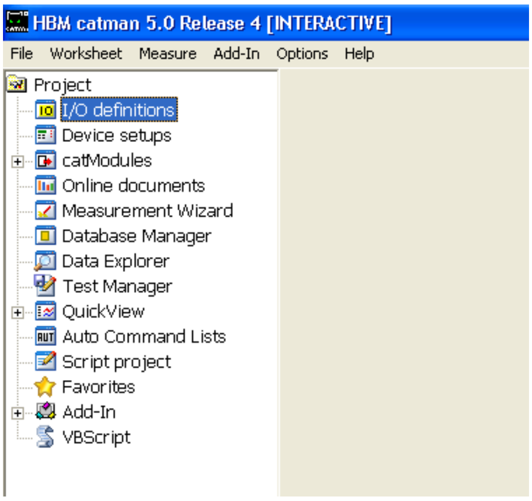
4. The cable from the CPT is connected to Spider 8 via the cable box mounted on the load beam. To Spider8 is also connected.
5. The speed of the CPT penetration is set to 5 mm/s.

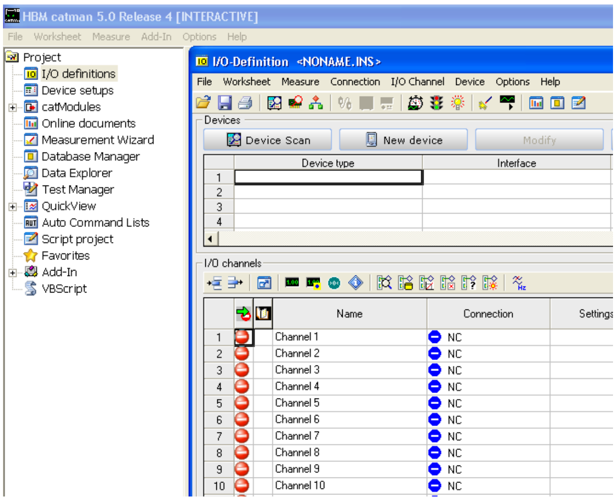
6. The CPT device is lowered until the tip of the CPT cone is right above the soil surface.

9. Catman is started.

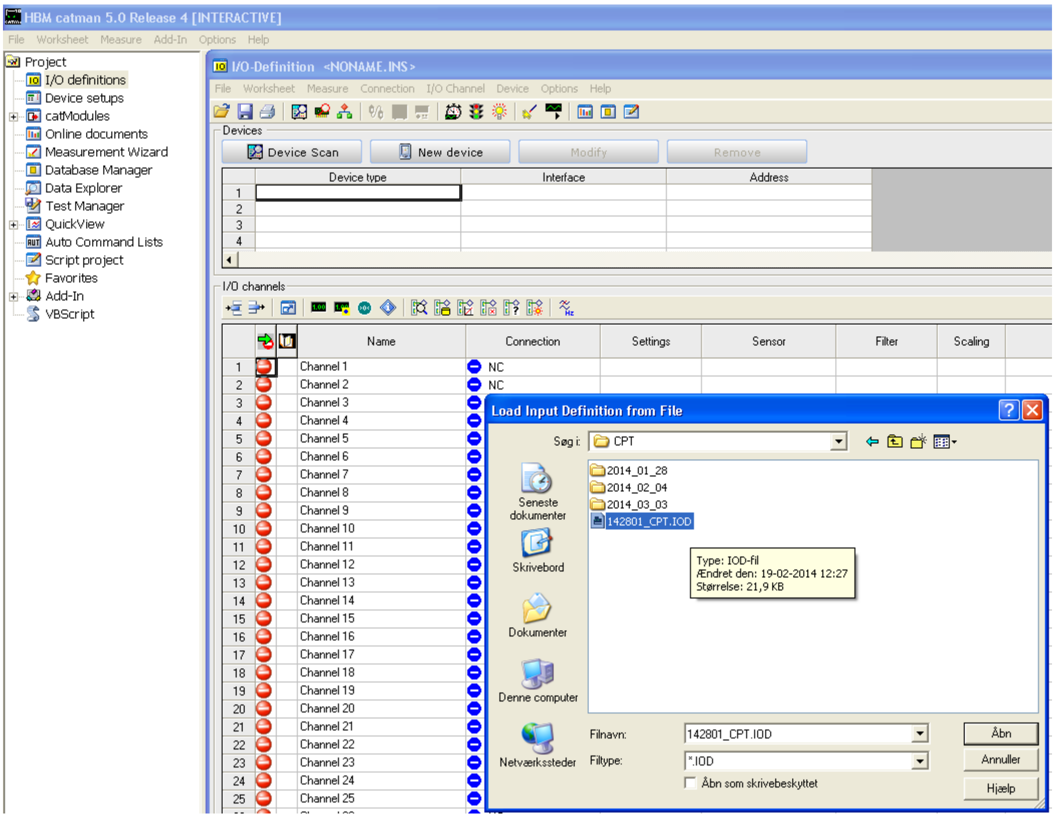


10. Press “I/O Definitions”

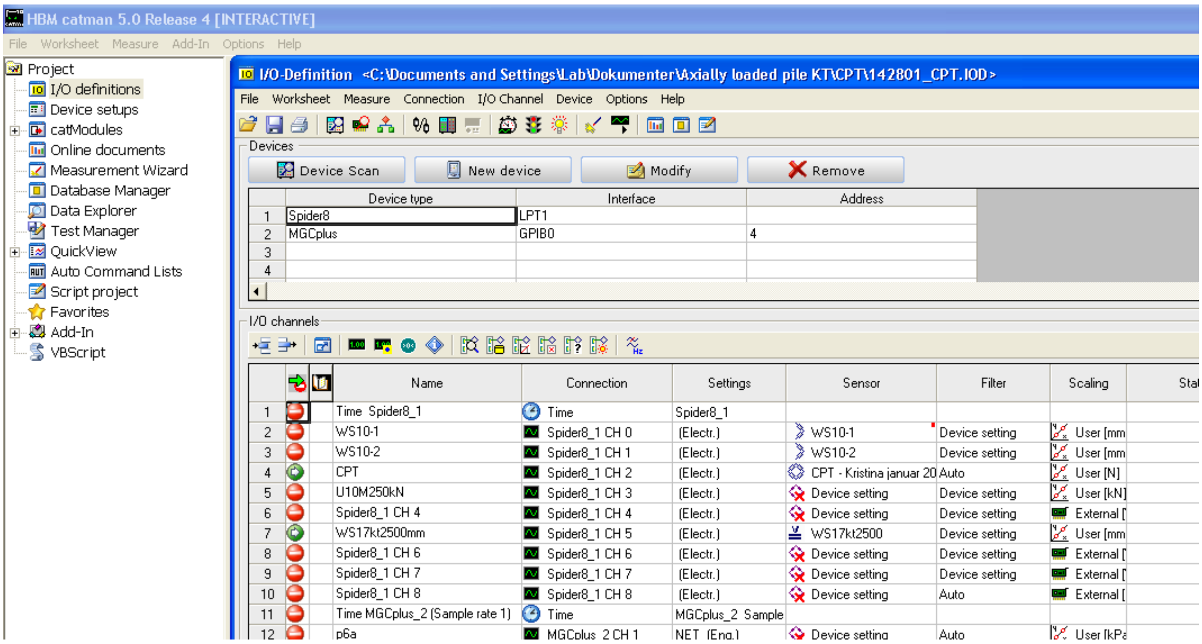




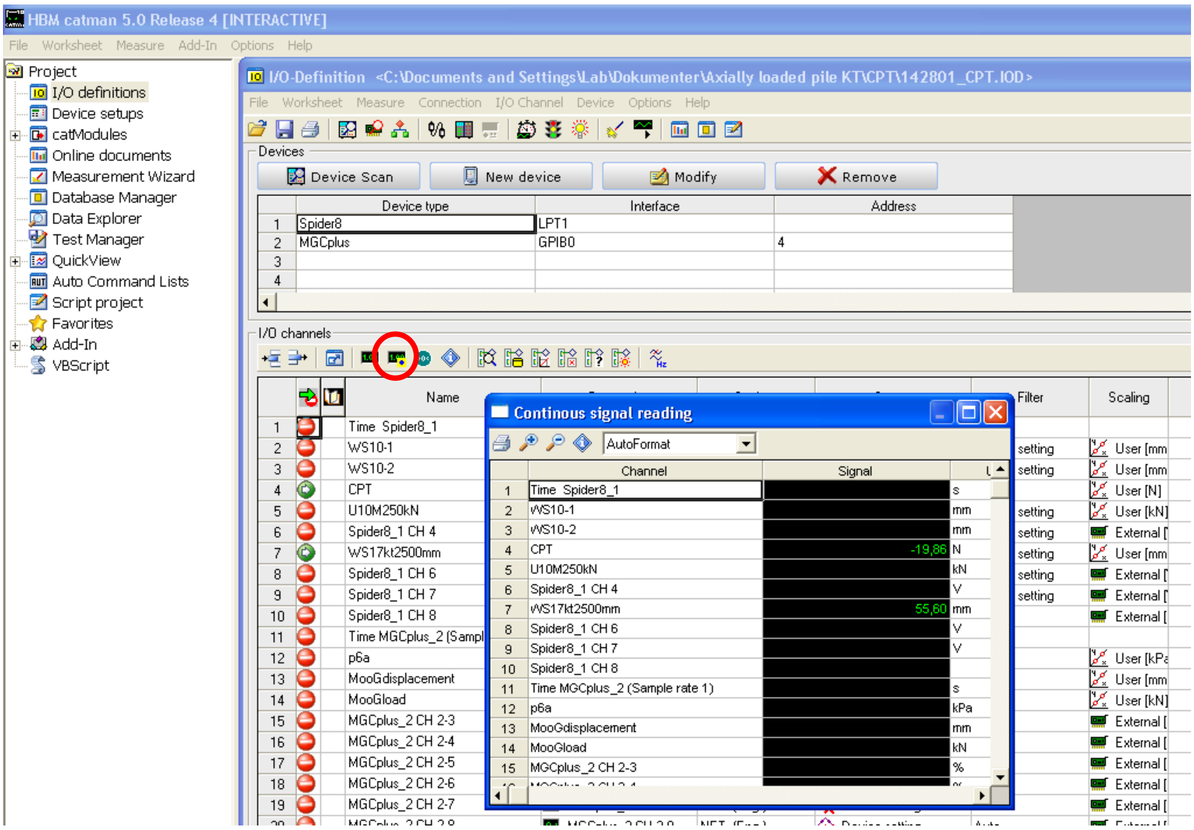
11. The file used for CPTs is opened (C:\Documents and settings\Lab\Dokumenter\Axially loaded pile KT\CPT\142801_CPT.IOD).



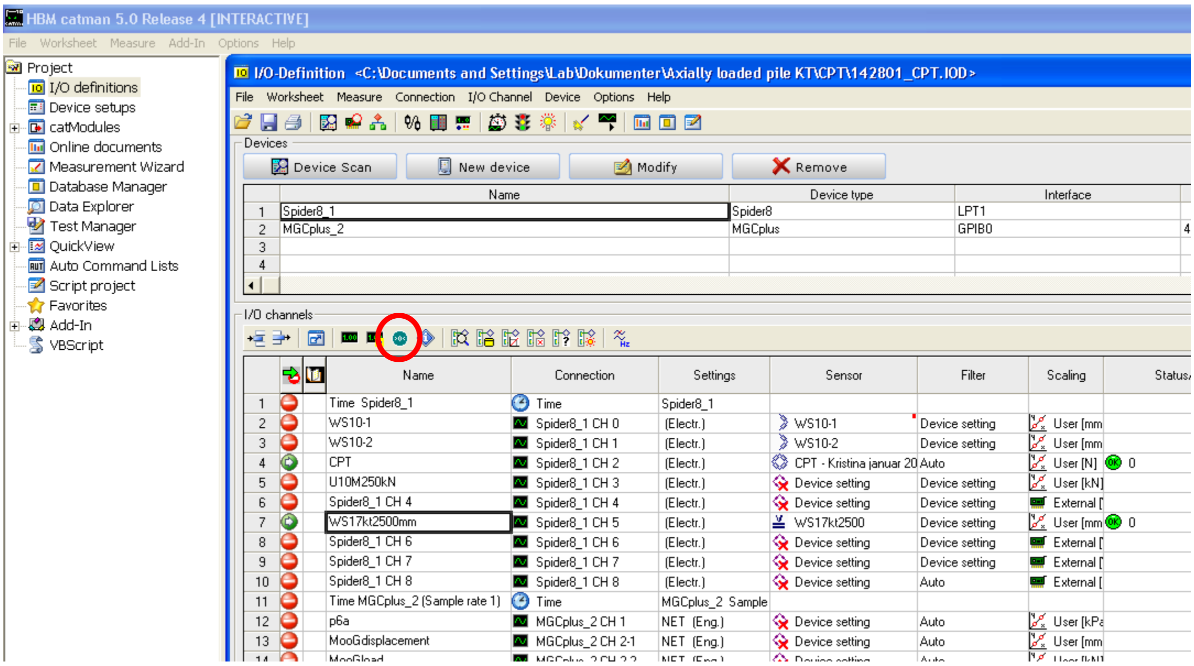
12. If the correct file is opened, a list of devices is shown. Most of these devices are marked by a red stop sign to the left. The only two active devices (Marked by green) are CPT and WS17kt2500mm, which is the displacement transducer. It is important to check if the correct calibration file is used for the CPT device. The correct file is loaded into the column "Sensor" in the way it is described in (Thomassen 2015).



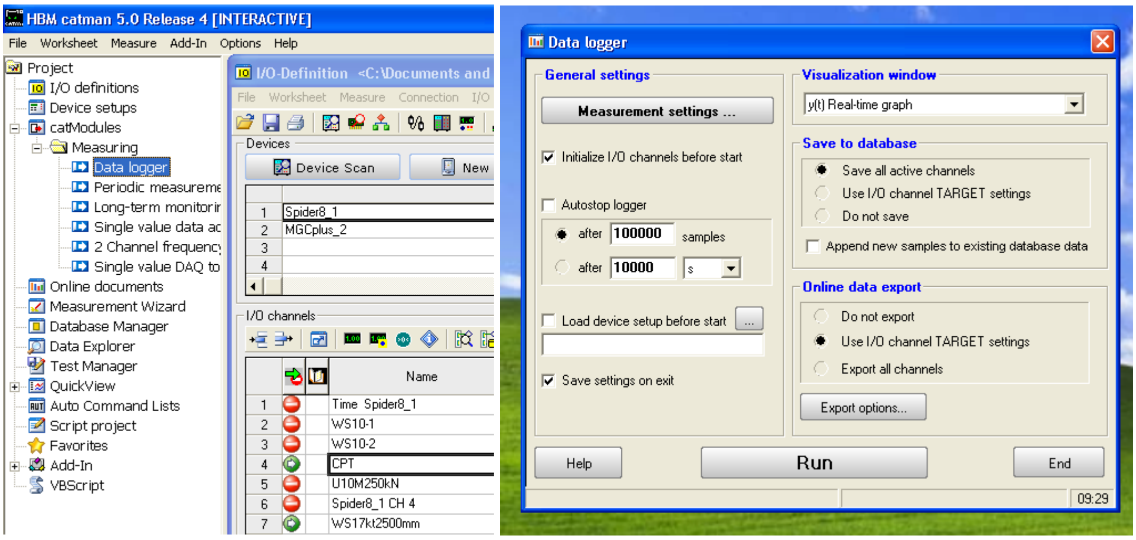
13. The momentary measurements of the devices can be seen by pressing the icon in the figure marked with a red circle.



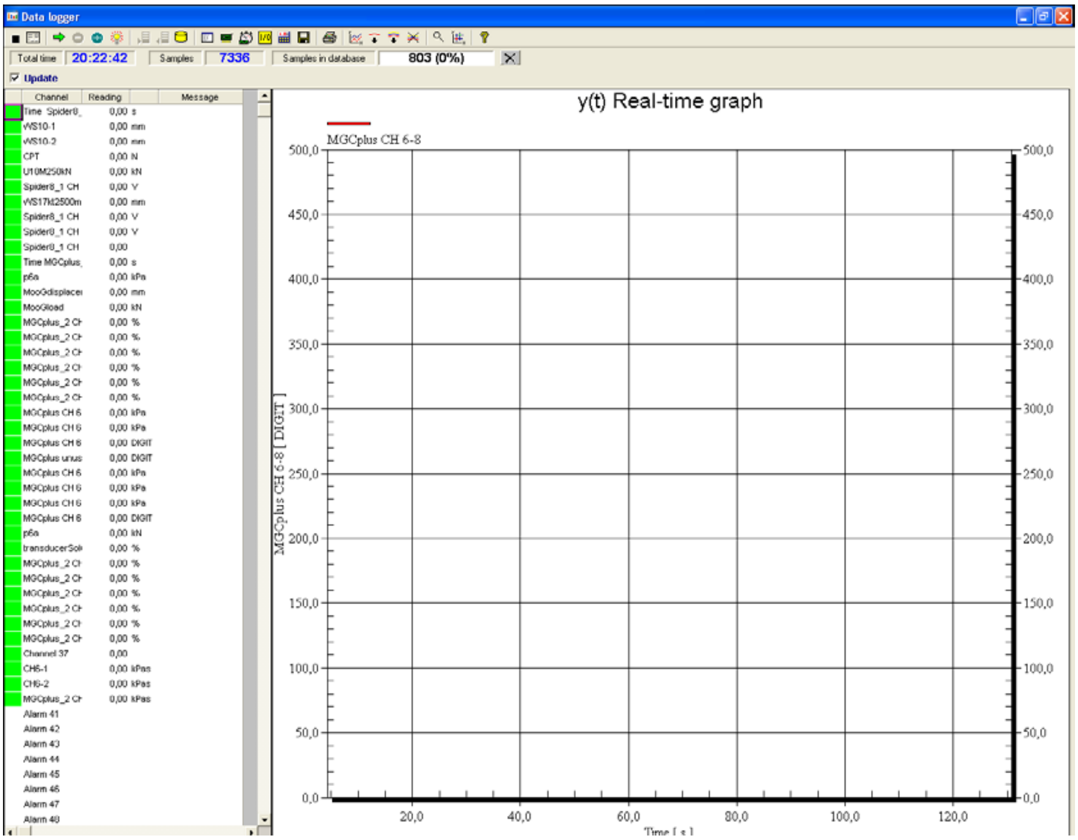
14. The measurements are reset by marking the wanted device and press the reset button, in the figure marked with a red circle. The column "Status/Reading" then shows a green mark and a zero (or a number very close to zero).

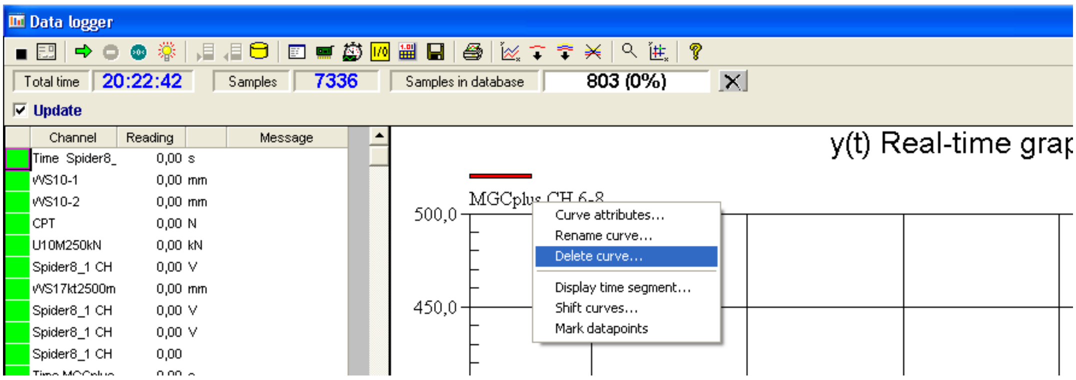


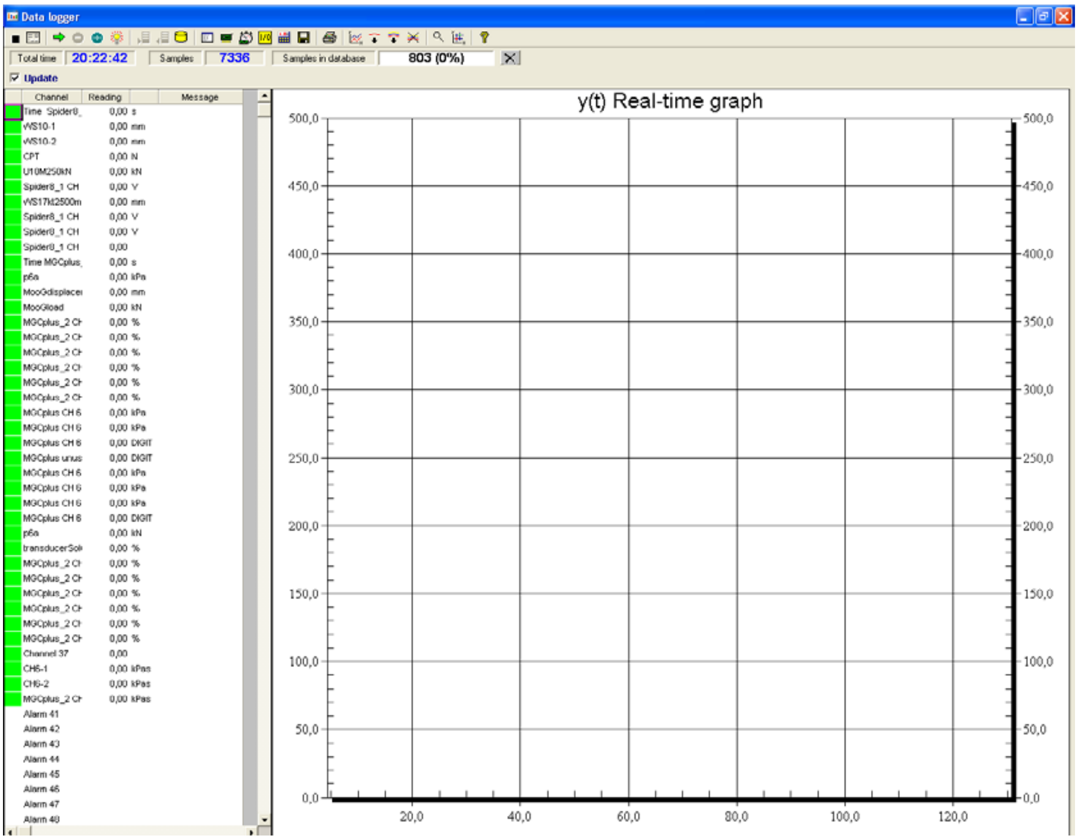
15. To start recording the measurements, press CatModules\Measuring\Data logger in the directories. Accept the standard settings and press Run.



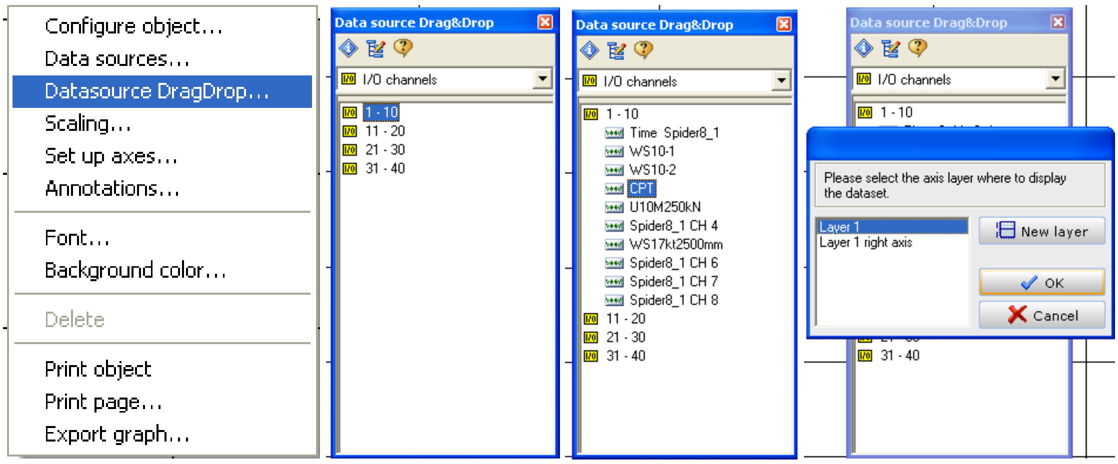
16. A graph will then show up. If the axes are not empty, the current device/devices shown in the top of the graph is/are deleted (example with MGCplus CH6-8).

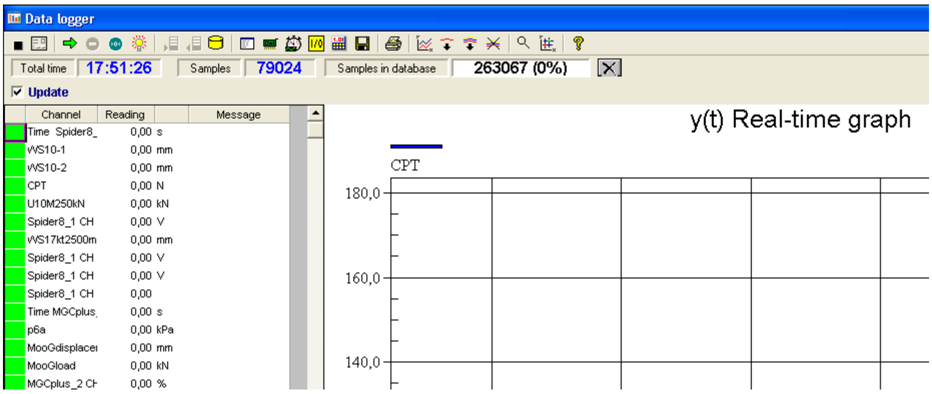

Data logger
Total time 20:22:42
Samples 7336
Samples in database 803 (0%)
Update
Channel
Reading
Message
y(t) Real-time graph
MGCplus CH 6-8
MGCplus CH 6-8 [DIGIT]
Time [s]


Data logger
Total time 20:22:42
Samples 7336
Samples in database 803 (0%)
Update
Channel
Reading
Message
Time Spider8_ 0,00 s
WS10-1 0,00 mm
WS10-2 0,00 mm
CPT 0,00 N
U10M250kN 0,00 kN
Spider8_1 CH 0,00 V
WS17kt2500m 0,00 mm
Spider8_1 CH 0,00 V
Spider8_1 CH 0,00 V
Spider8_1 CH 0,00
Curve attributes…
Rename curve…
Delete curve…
Display time segment…
Shift curves…
Mark datapoints

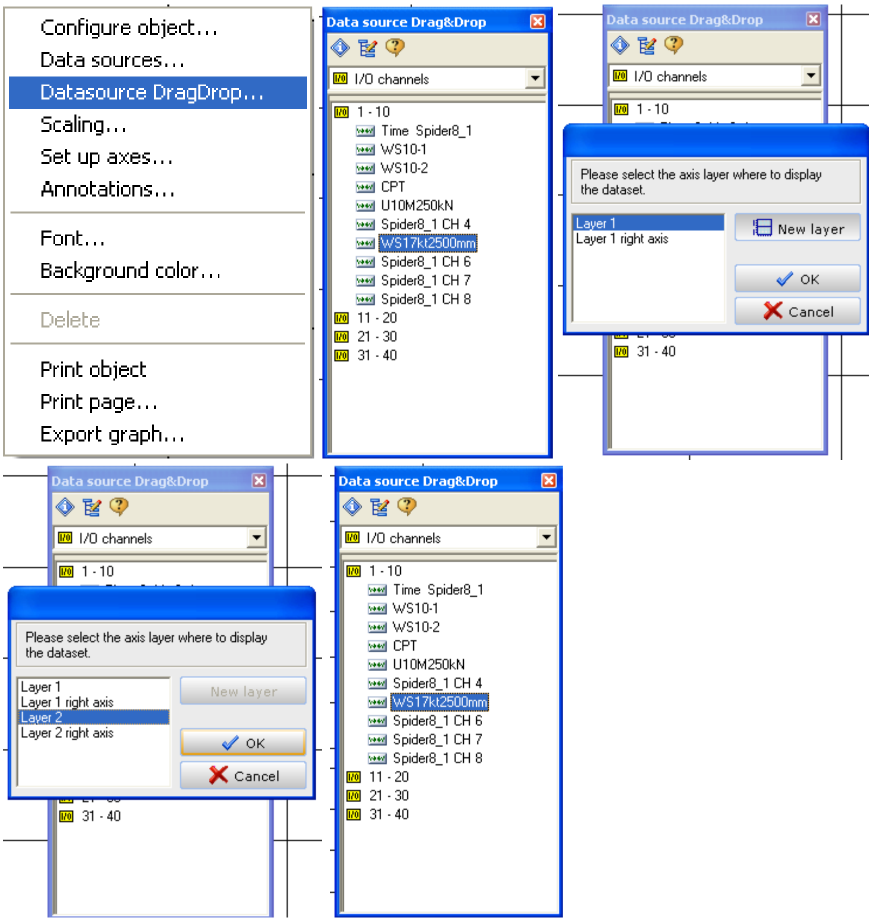


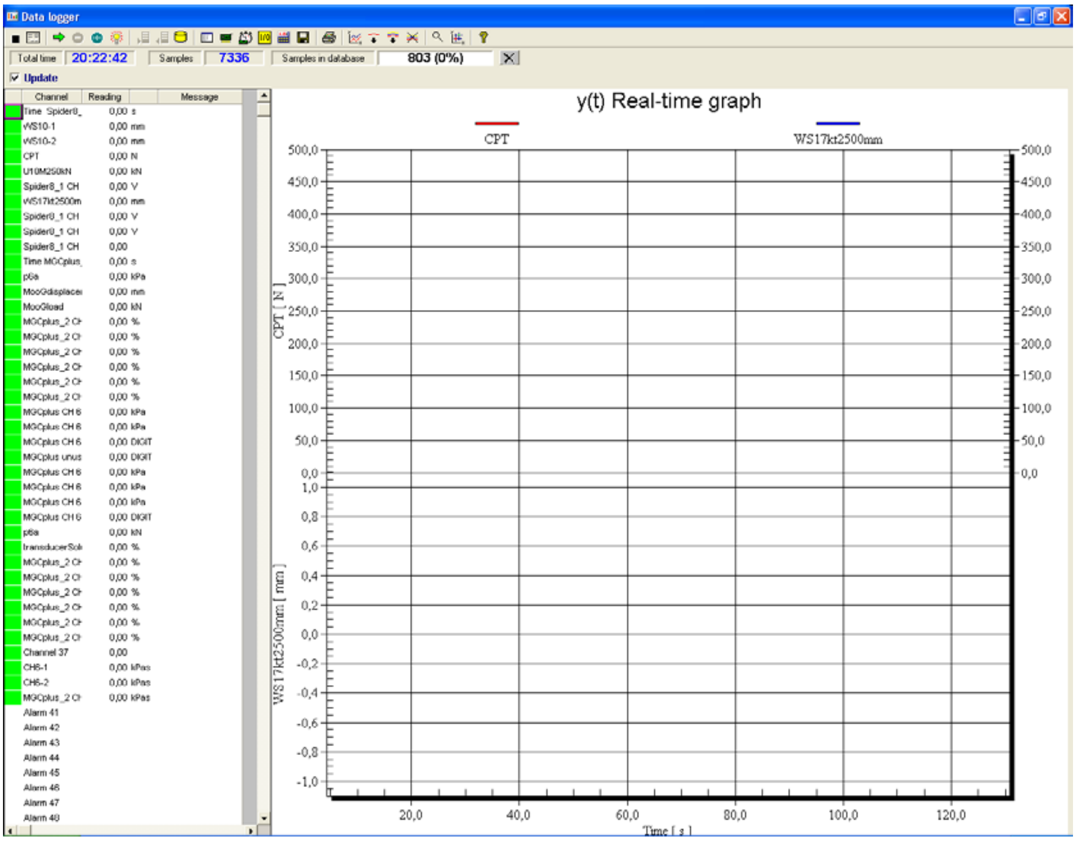
17. A menu appears when right-clicking on the graph. Choose "Datasource dragDrop" and another menu with the list of devices appears. Left-click on "CPT" and drag it to the graph. When letting go of the mouse button, a menu appears in which "Layer 1" is chosen. Now the measurements from the CPT device is shown in the graph during a CPT.





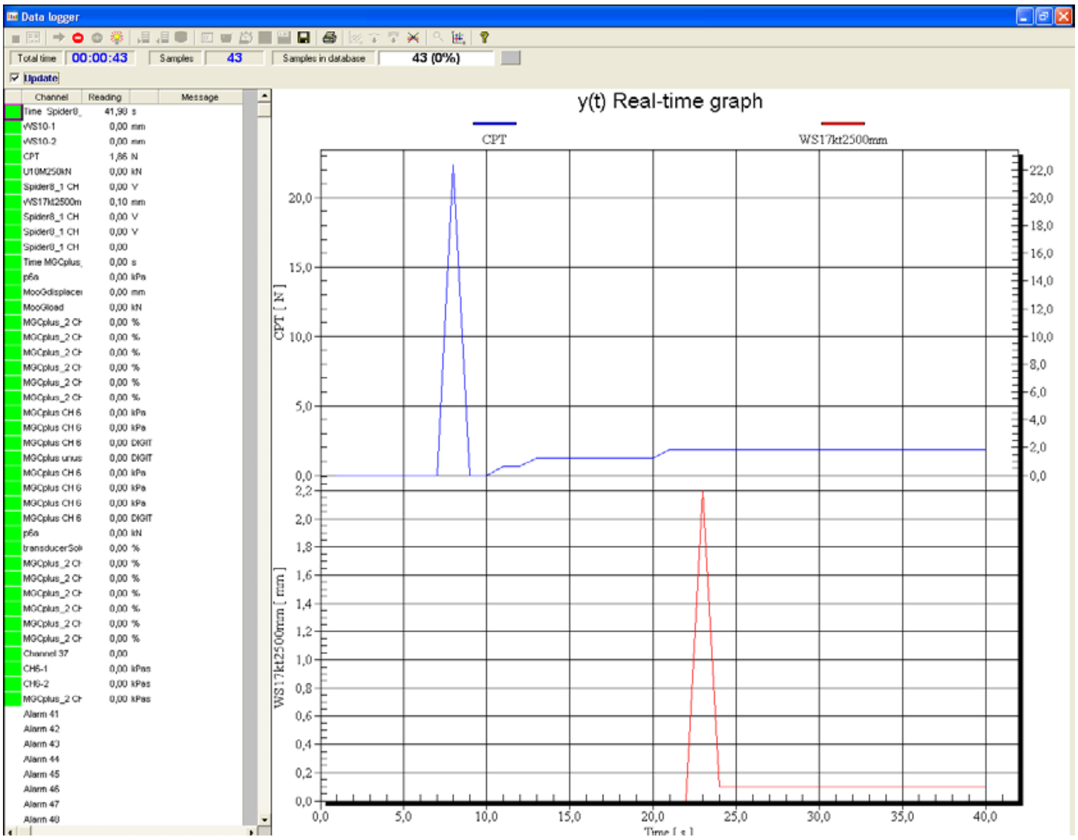
18. To monitor the displacement, the same can be made for the displacement transducer. To show the measurements in two different graphs, press "New layer" and choose Layer 2.





Check that the cone resistance and the displacement is measured.

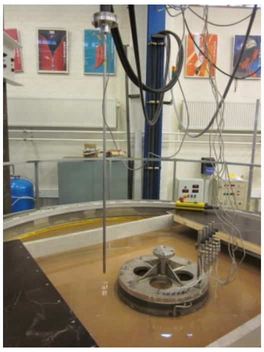
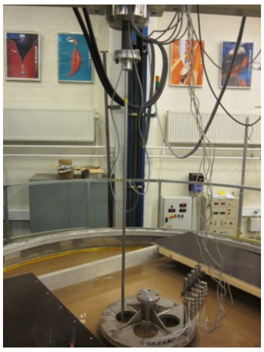
1) Start the measurements in Catman, by pressing the green arrow in the upper left corner of the window.
2) Press on the CPT cone and pull the wire of the displacement transducer gently to see if Catman shows any fluctuations. If there is no signal from one or both devices, check if the setup in Catman is correct. If this is not the problem check that the devices are properly connected and that the wires and connections are intact. If nothing works contact the craftsman in charge of the test setup.



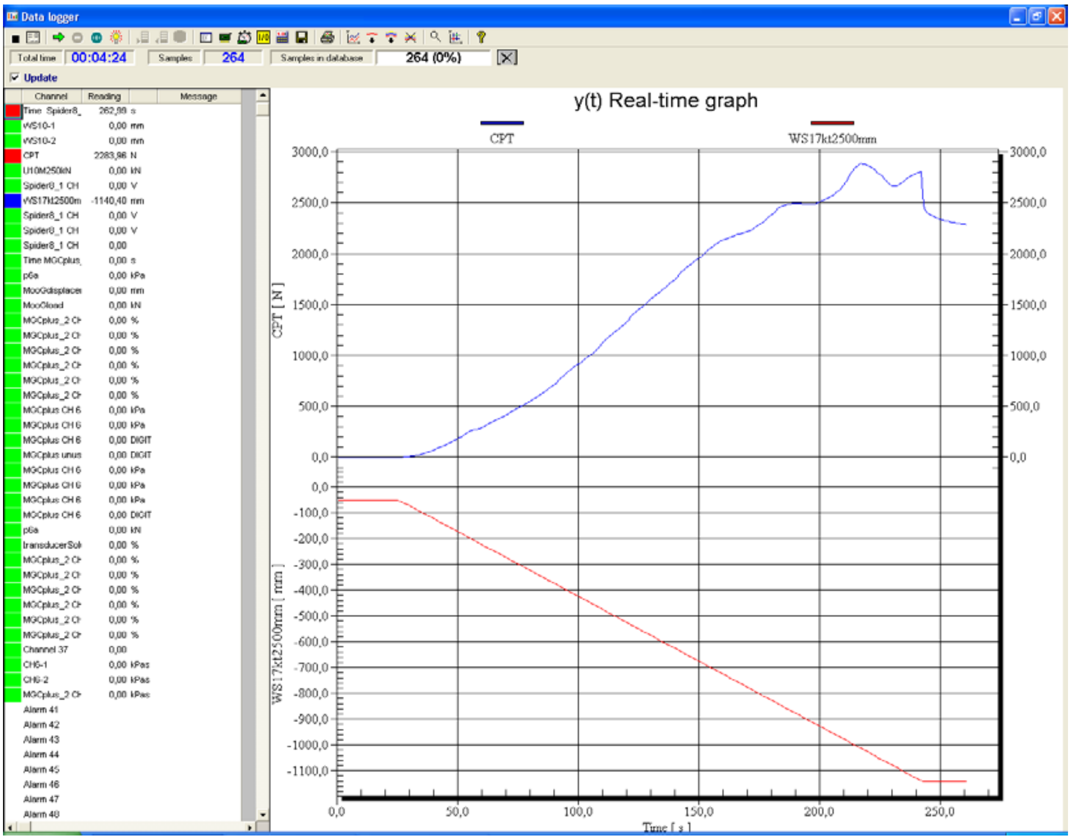
3) Stop the measurements on the red stop sign in the upper left corner of the window and press “No” to saving the data.

Conducting a CPT

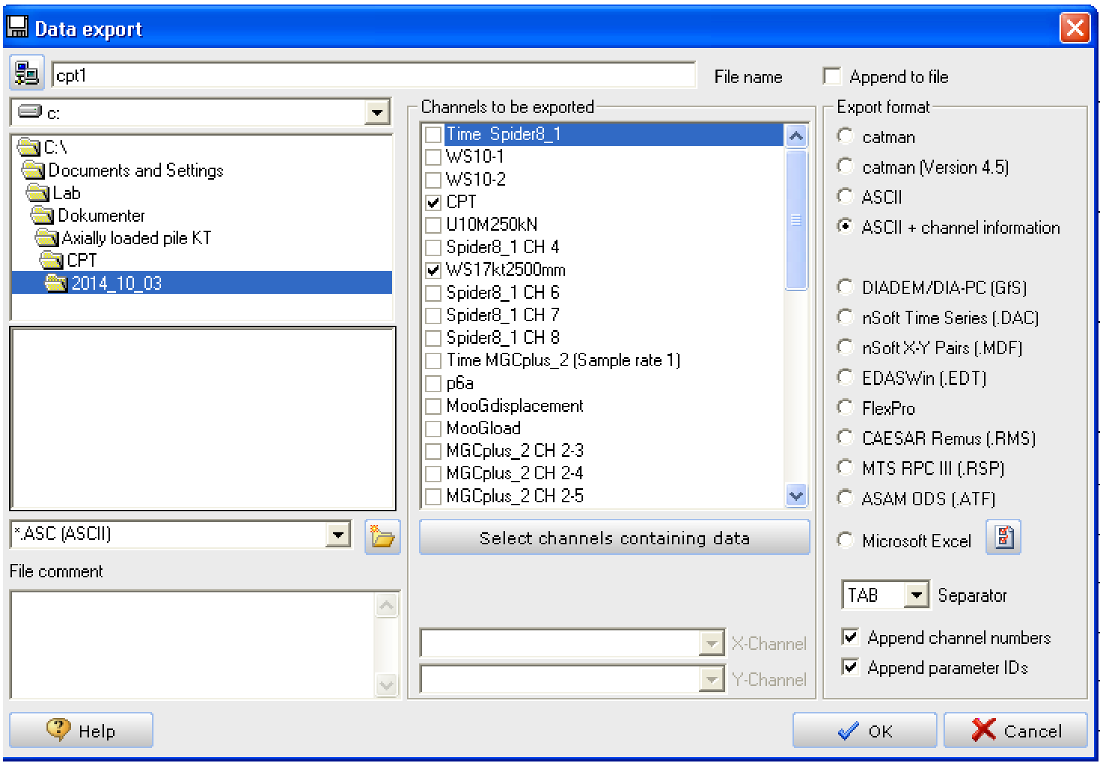
1) The CPT cone resistance and the displacement are reset in Catman if it has not already been done. The I/0 Definition can be found in the menu in the Data logger.
2) Make sure that the knob on the hydraulic piston controller is in the upper or middle position so that the speed of the penetration is 5 mm/s.
3) Data acquisition in Catman is started. Catman records the measurement from the devices that are marked by a green circle in “I/0 Definition” even if they are not chosen in the graphs.
4) Hereafter hydraulic cylinder 1 is started and the cone penetrates the soil surface.


5) When the CPT cone reaches a depth of 1100 mm the penetration is stopped along with the data acquisition.



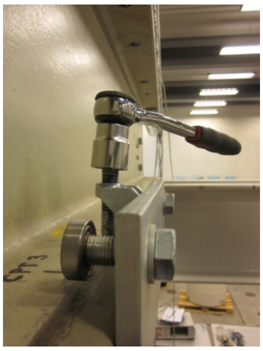
6) The data is saved as ASCII+channel information. Un-tick the devices not in use, and tick off the ones, that are to be saved in the file (Time Spider8_1, CPT, WS17kt2500mm).



7) The CPT is pulled out of the soil by means of hydraulic cylinder 1.

Conducting CPT 2 and the following CPTs

1) The screws on the rack holding hydraulic cylinder 1 are loosened and it is moved to the next position and fastened as described before.

2) Fasten the rack at this new position and conduct the CPTs as described before.

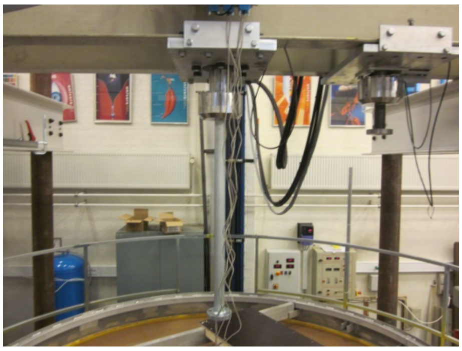
After conducting the five CPTs the results are interpreted as described in (Thomassen 2015).

1) If the results are not satisfactory, meaning that the soil density is not alike for all five tests and not corresponding to values from previously done tests, the procedure of loosening the soil, vibrating and conducting CPTs are repeated until satisfactory results are obtained.
2) If the results are satisfactory, the CPT equipment is removed from hydraulic cylinder 1.

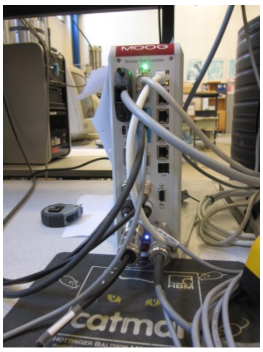
5 Preparations prior to Tests

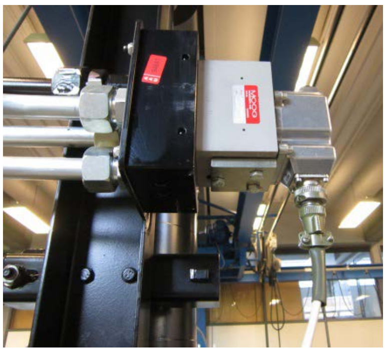
Connecting the pile to hydraulic cylinder 2:

1. Hydraulic cylinder 1 is moved to the right side of the load beam.
2. Hydraulic cylinder 2 is moved to the middle of the load beam and the eight bolts are inserted in the holes but are not tightened to the load beam yet.



3. Connect the load cell and the displacement transducer to the MOOG Modular Test Controller.

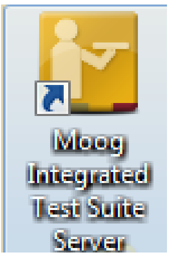


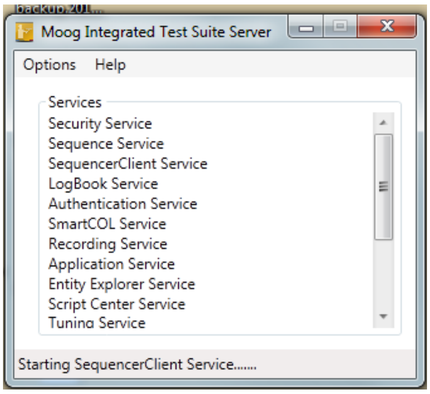


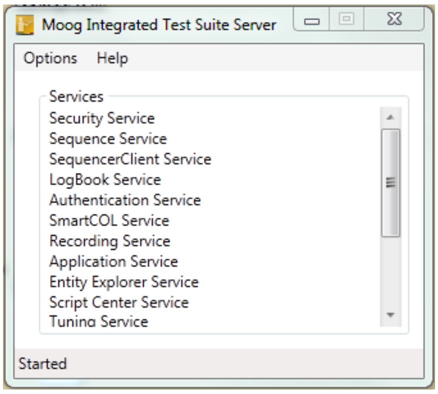
To move the cylinder up and down, the program MOOG must be used. Firstly, a project is started:

1. The MOOG computer is turned on.

2. MOOG Integrated Test Suit Server is started.

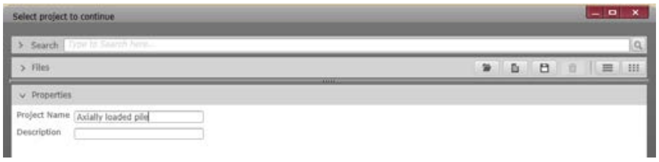


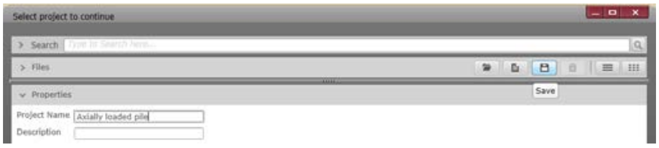


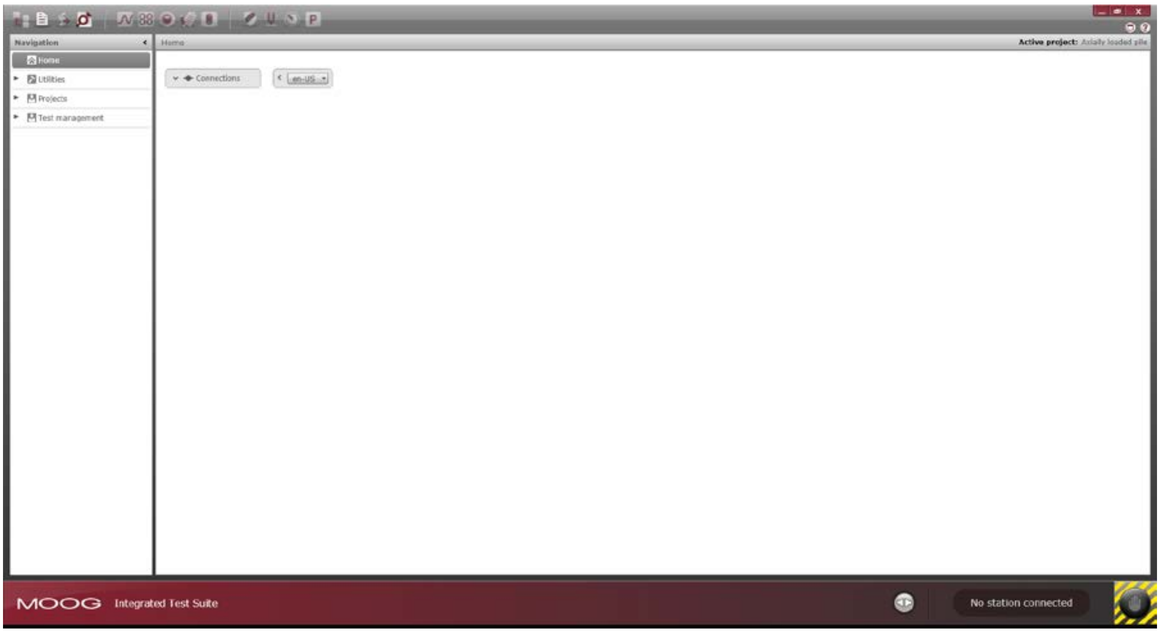


3. MOOG Integrated Test Suit Client is started and it is chosen either to create a new project or to open an existing one.

4. If create new project is chosen, a project name is written in the box and Save is pressed.

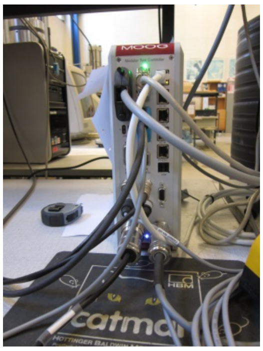




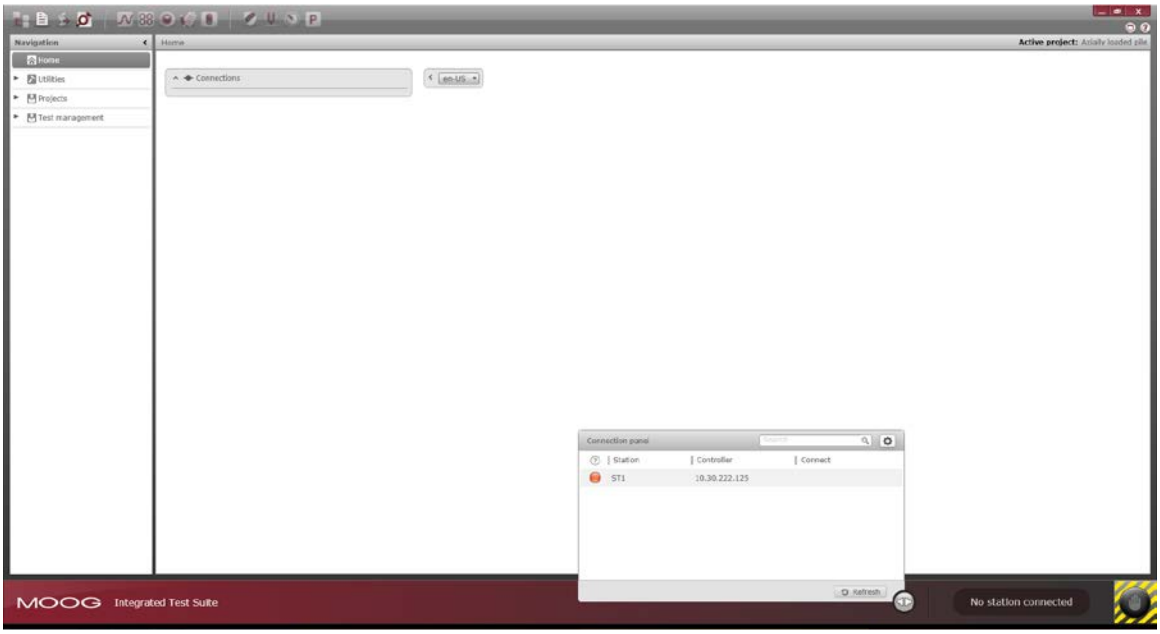


The program and the test controller are connected:

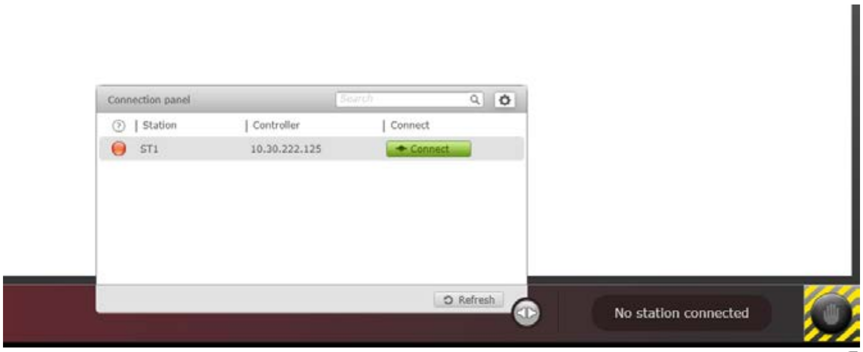
1. Check that the MOOG Modular Test Controller standing next to the computer is on and ready (green light at the top and blue light at the bottom).

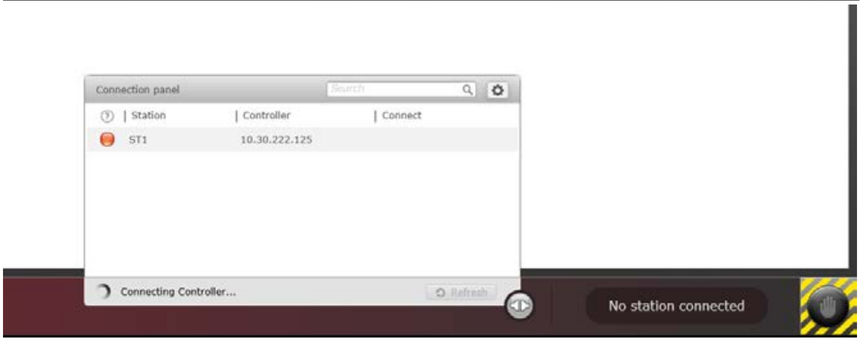


2. Press the gray button in the lower left corner.

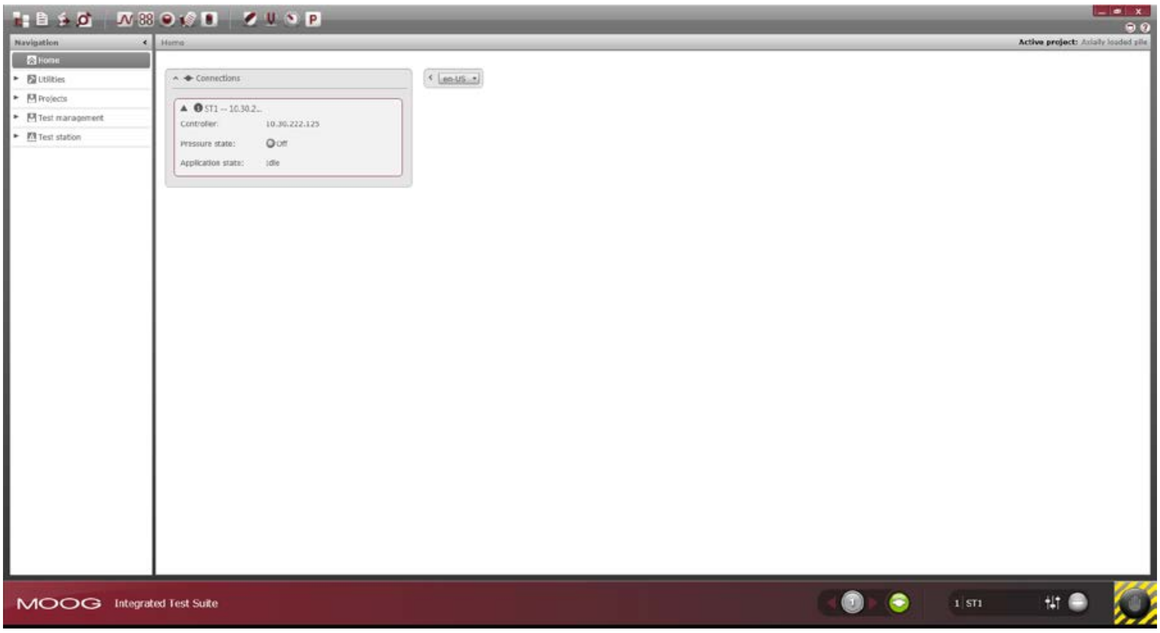


3. Press the green button "Connect" (appears when the mouse is held over ST1 line).



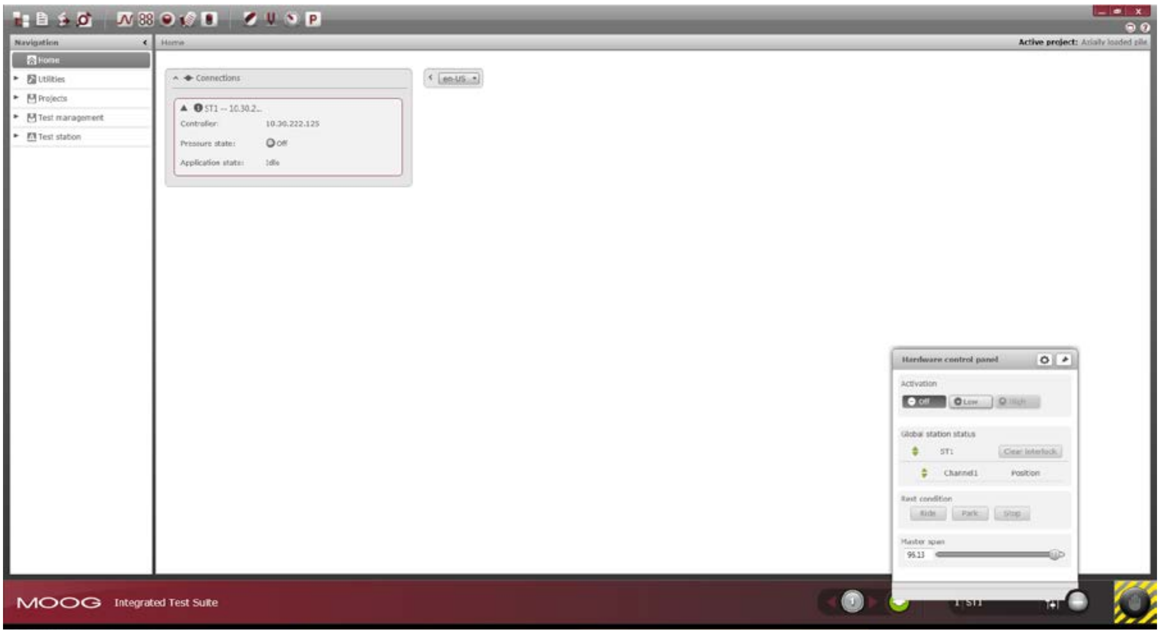


4. At the bottom bar a grey circle with the number 1 (Station 1), a green circle and station bar show up.

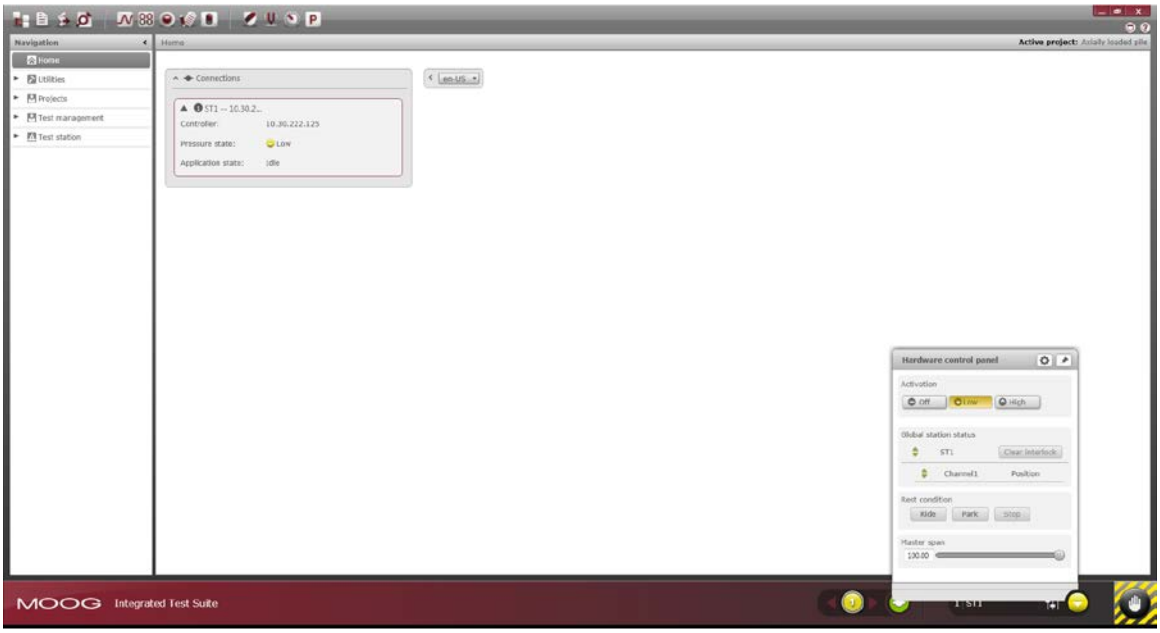


The hydraulic pump which is used to apply load to the pile is started.

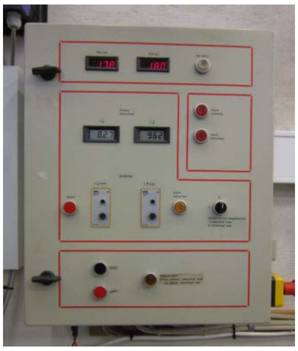
1. Press the grey button in the station bar.
2. The activation is on “Off”.

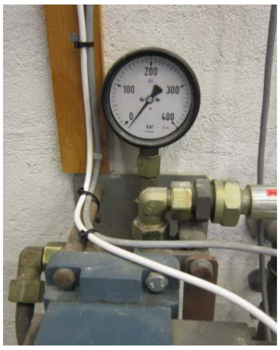


3. Press “Low”.

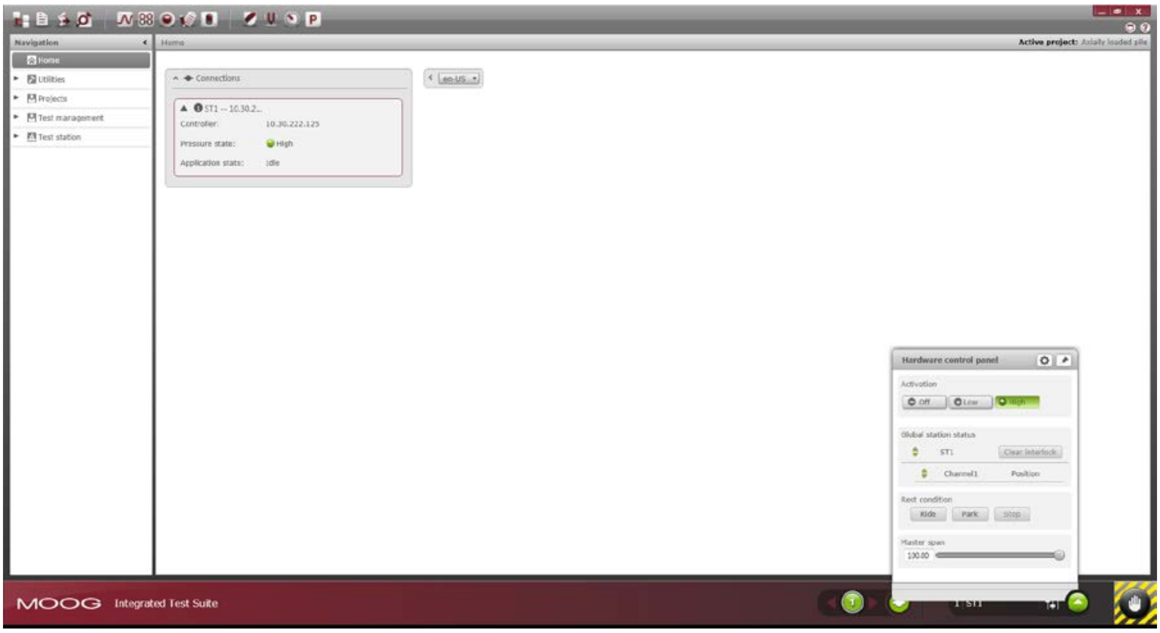


4. Turn on the hydraulics. You can hear the oil running into the hose and the manometer turns from 0 bars to 200 bars.





5. Press “High”. The pressure in the hose rises. Be aware that the cylinder may move due to the pressure raising. Do not have fingers or the like underneath the cylinder at any time when the hydraulics is on.

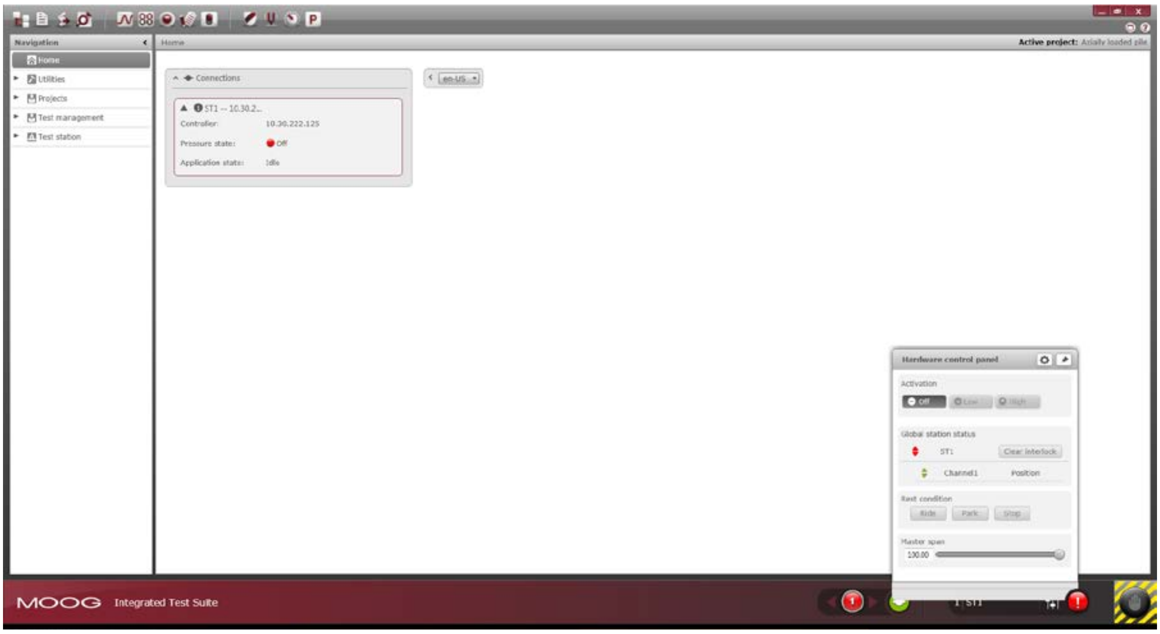


6. Check that “Master span” is 100.00. If it is lower than 100 percent this will affect the results of the tests. If Master span is 60.00 and a displacement of 100 mm is chosen for a displacement controlled test, hydraulic cylinder 2 will only move 60mm. The same reduction will happen if the test is run force controlled.

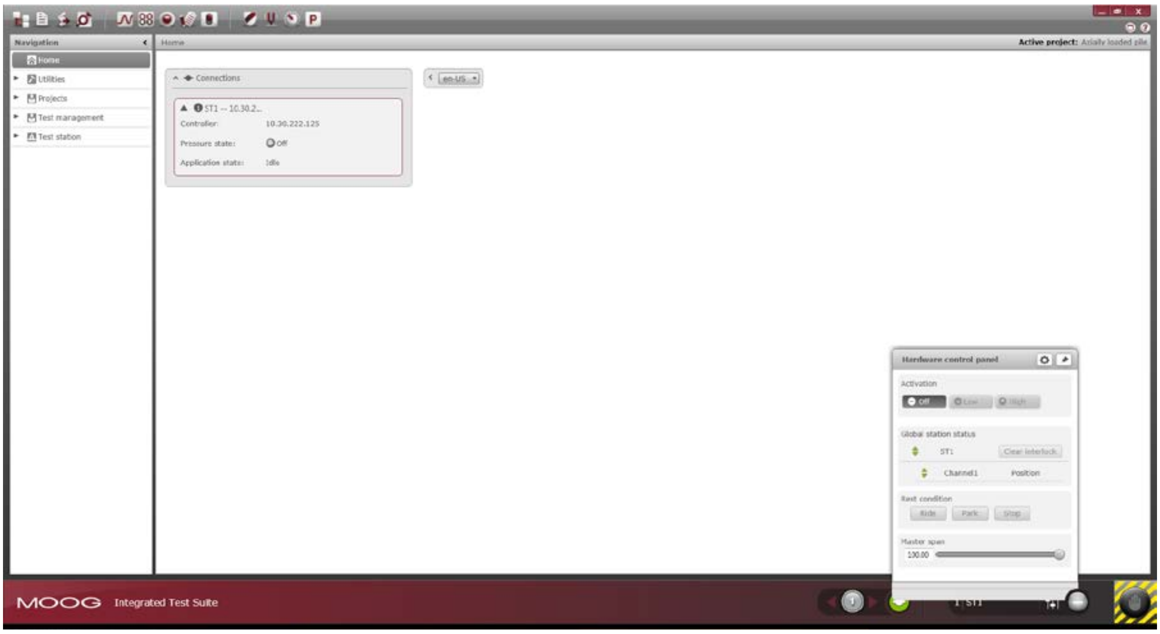
Procedure in case of emergency (or if something where everything should be stopped immediately) while the hydraulics is turned on.

1. Press the emergency stop button.

2. When the emergency stop is pressed, the connection between the station and the computer is disconnected and the hydraulic cylinder will stop moving immediately.



3. To reconnect, turn the emergency stop button in the direction of the arrows on the knob and press “Clear interlock” which will be flashing.

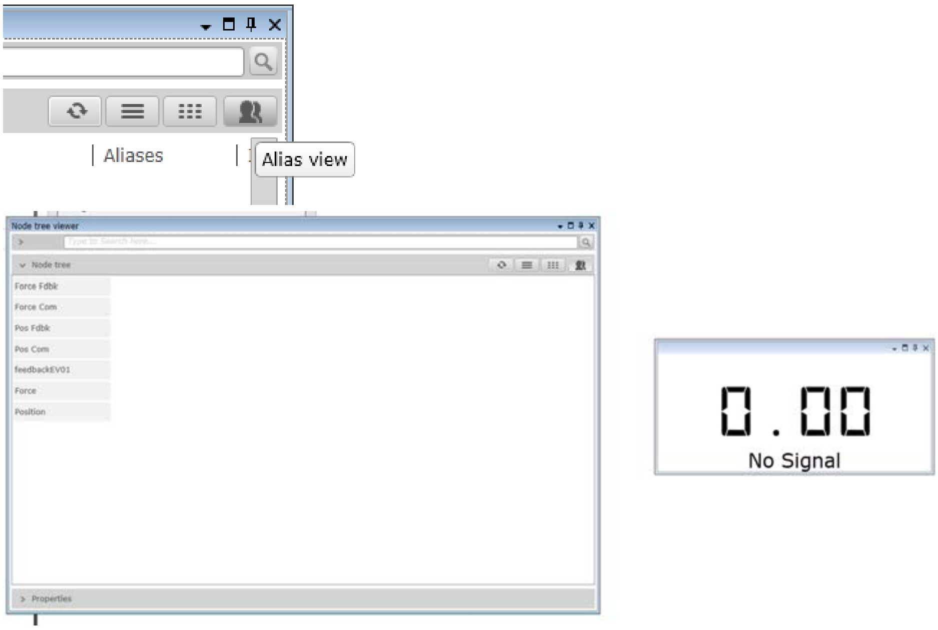


Hydraulic cylinder 2 is connected to the pile.

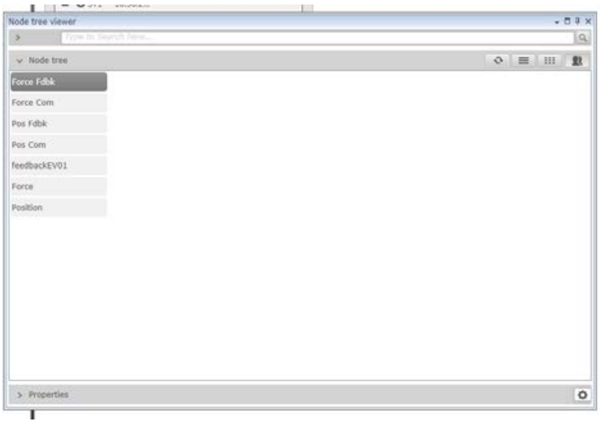
1. The force is monitored during connection in a display.
2. Press “Digital meter” in the top bar.

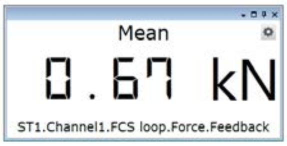
3. Press “Node tree viewer” in the top bar

4. Press “Alias view” in the upper left corner of the new dialog box.

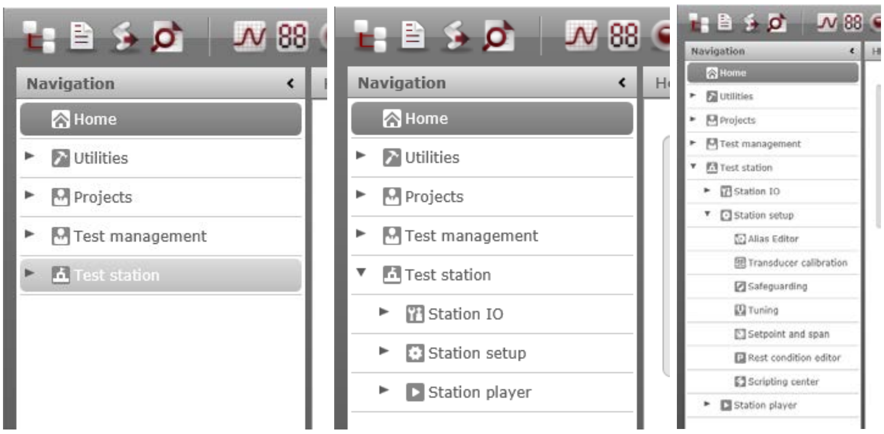


5. Drag “Force Fdbk” into the Digital meter box.

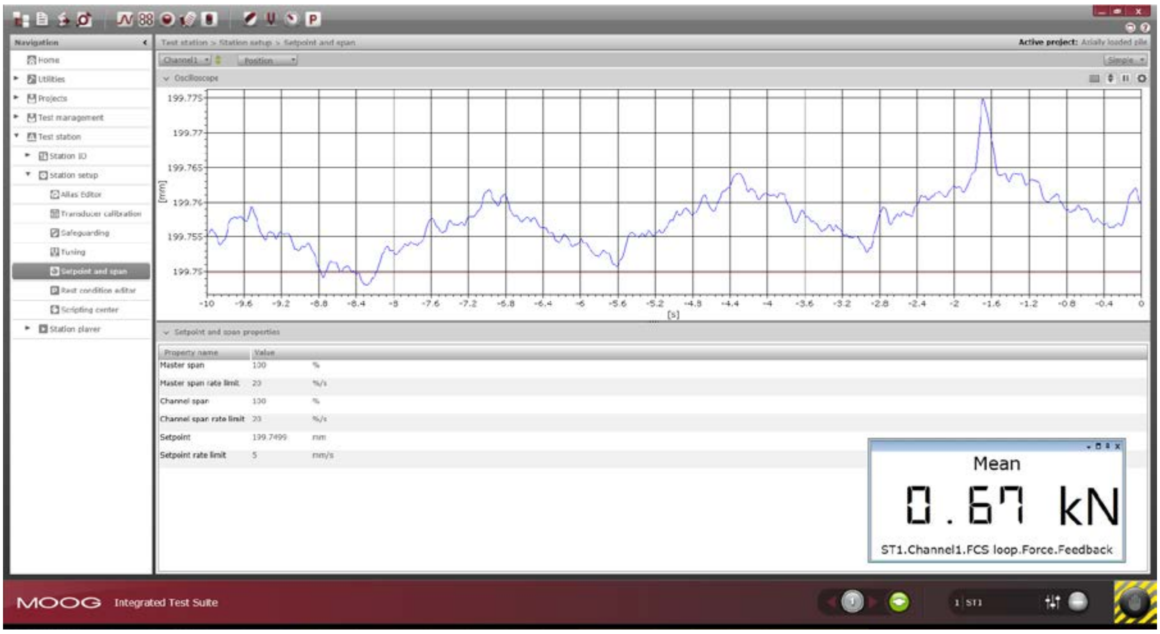




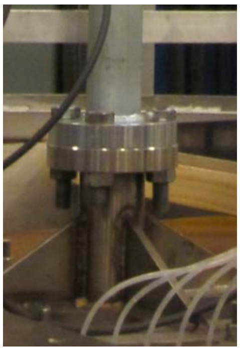
6. Close “Node tree viewer”.
7. Press “Test station” in the left menu, then press “Station Setup”.



8. Press “Setpoint and span”. The graph shows the position of the hydraulic piston at the given time. “Setpoint” is the position of the hydraulic cylinder; 200 mm means that the cylinder is in its uppermost position. The span of the cylinder is from 200 mm to -200 mm. By changing the number in “Setpoint”, the cylinder moves to the given position with the speed given in “Setpoint rate limit”. Be aware that MOOG does not register the changes made before “Enter” is pressed.



9. Move hydraulic cylinder 2 slowly down until it touches the pile. Connect the pile and hydraulic cylinder 2 with four bolts.

10. Tighten the eight nuts on the flanges of hydraulic cylinder frame.

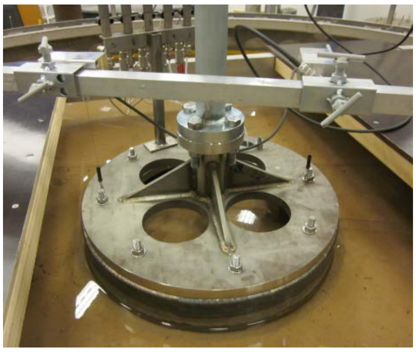
5.1 Prior to Tests without Membrane

The displacement measured by MOOG cannot be trusted especially when running cyclic loading tests, therefore, two external displacement transducers are mounted on top of the pile to get the correct displacement.

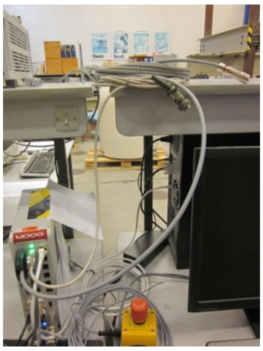
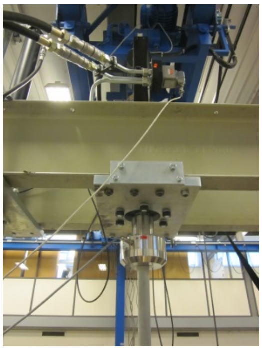
1. An aluminium bar is placed across the sandbox with two displacement transducers mounted on.


2. The transducers are adjusted so that they are placed right over two of the nuts on the pile lid, on which of each a screw is attached.

3. The aluminium bar is clamed to the sand box edge.
4. The line from the displacement transducers should be fixed to the screws and be vertical. This way the displacement of each side of the pile is measured alongside the displacement measured by MOOG.



5. The transducers are connected to the box on the load beam, which connects them to the MGC.
6. The load cell and the displacement transducer are connected to the MOOG system.

5.2 Prior to Tests with Membrane

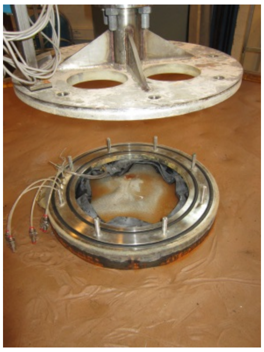
Removing the pile lid:

1. Loosen and remove the eight nuts keeping the pile lid and the pile flange together.


2. Close the valves positioned right below the pore pressure transducers with a screw driver.

3. Disconnect these valves from the small piece of hose connecting them to the pore pressure transducers.

4. Open the valves above the pore pressure transducers so the water flows out of them.
5. Move the pile lid slowly upwards using “Setpoint and span” in MOOG to Hydraulic cylinder 2’s uppermost position while leading the hoses from the pore pressure transducers through the hole in the pile lid. (No fingers between the pile lid and pile flange when the hydraulics is turned on!)

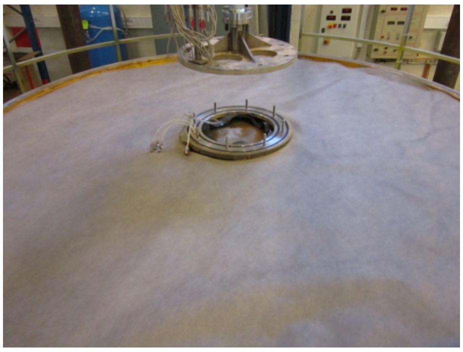
6. Turn off the hydraulics.

To prevent the membrane to be sucked underneath the pile flange during a test, a tube is placed under the pile flange. It is later inflated to the same pressure state as applied to the membrane:
1. Place the round piece of felt cloth on the sand surface inside the pile.
2. Place the tube underneath the pile flange.


Removing aluminium frame 1:
1. Remove the footbridges and the aluminium bars.
2. Unclamp aluminium frame 1 and remove it from the test setup (two-man job).
3. Remove the thick rubber ring from the groove in the sand box edge. Clean it and leave it to dry.

Placing the membrane:

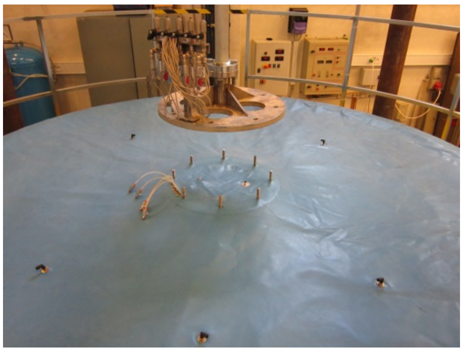
1. Place the large felt cloth on the sand surface.



2. Clean the pile flange with the compressor.
3. Clean the groove in the sand box edge with paper/cloth and compressor.
4. Place the thin rubber ring (l mm) in the groove.

5. Connect the hose from the tube under the pile flange to the quick-coupling on the underneath of the membrane; lead the hoses from the pore pressure pipes to through the long hole in the membrane, and lead the bolts on the pile flange through the corresponding holes in the membrane. Be careful not to pull the membrane too hard to prevent expansion of the holes in the membrane.

6. Lay out the rest of the membrane on the sand surface and leave it hanging from the sand box edge. The membrane is straightened to avoid bulges.



Sealing the sand box edge:

1. Press the round rubber ring (Ø = 9 mm) and the membrane into the groove in the sand box edge.
2. Place aluminium frame 2 on the sand box edge corresponding to the numbering on the frame and the sand box edge. Be careful not to push the round rubber ring out of the groove when placing aluminium ring 2.
3. Clamp the frame to the sand box edge with four clamps, one to each side of the setup. Hereafter, place four clamps between the first four clamps and so on until 32 clamps are used. Check that all clamps fit tightly.

Sealing the pile flange:

1. Start the hydraulics and lower the pile lid very slowly. It is, preferably, a two-man job; one sits next to the pile leading the hoses from the pore pressure pipes through the hole in the pile lid and ensuring that the bolts are lead through the holes in the pile lid; while the other controls the hydraulics with MOOG.

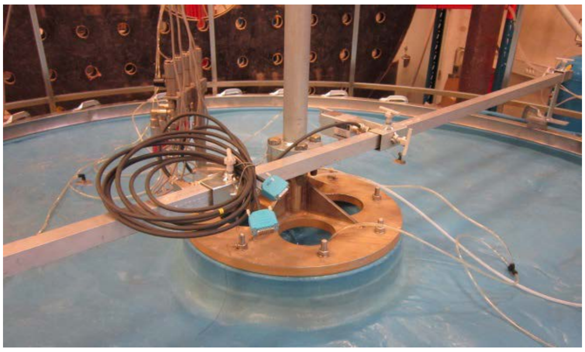
2. Tighten the nuts on the pile lid. Make sure that the two nuts with screws attached are placed opposite each other on the pile lid as they are used in the measurements of the pile displacement.

Re-saturating the pore pressure transducers (this procedure is somewhat meaningless as the recorded data suggests that measurements are incorrect and, thus, useless):

1. Use a syringe with water and press water into the tubes above the pore pressure transducer on the pile lid.
2. When the water flow is steady, press the hose into the quick-coupling below the pore pressure transducer.
3. Close the valves above the pore pressure transducers.
4. Open the valves on the hoses below the pore pressure transducers with a screwdriver.

Positioning displacement transducers:

1. Place the bar with the displacement transducers across the sand box and adjust the displacement transducers until they hang directly above the nuts with screws on the pile lid.

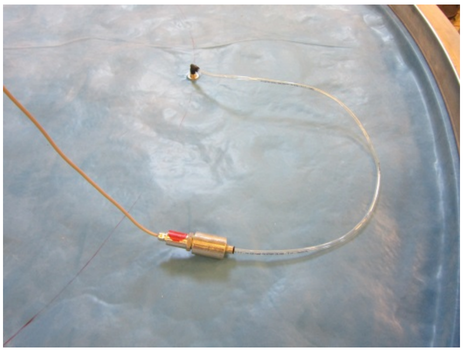


2. Clamp the bar to the sand box edge.

3. Connect the transducers to the box on the load beam.

Connecting pressure transducer to membrane:

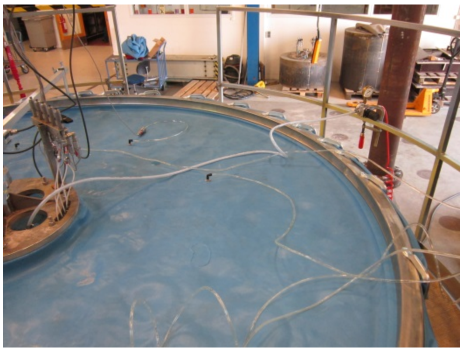
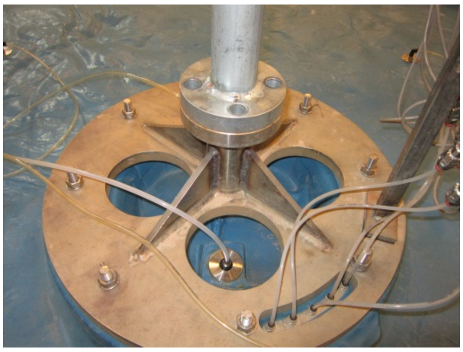
1. The pressure transducer is connected to the box on the load beam and to the quick-coupling on the membrane.



Applying pressure to the tube under the pile flange:

1. Place the manometer somewhere on the setup and connect it to a compressor outlet.

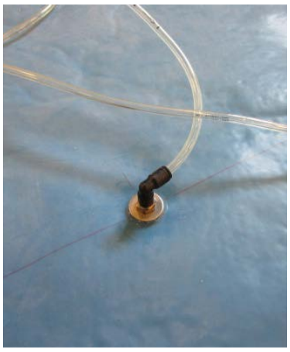
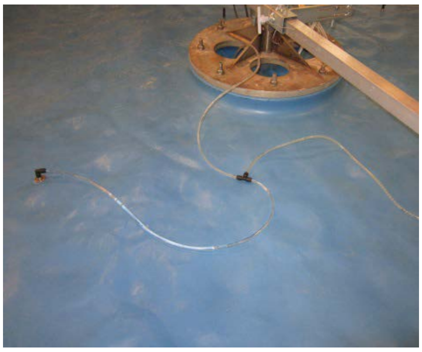
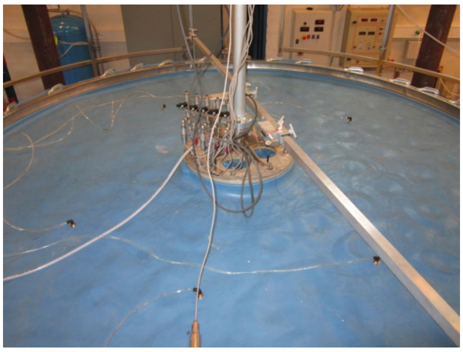

2. Connect the manometer to the tube thought the quick-coupling on the membrane inside the pile.

3. The pressure is applied gradually when the suction on the membrane is applied.
4. Before running a test, the pressure in the tube should correspond to the suction on the membrane.

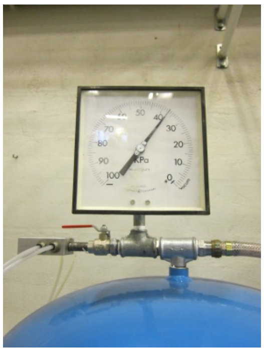
Applying suction to the membrane:

1. Couple the hoses from the vacuum pump to the four quick-couplings on the membrane outside the pile. By means of a three legged quick-coupling the last hose should be divided in two and one of the ends connected to the quick-coupling on the membrane inside the pile.

2. Start Catman and load the appropriate I/O-file for the MGCplus during tests.
3. Reset the pore pressure transducers and the pressure transducer measuring the membrane suction.
4. Make a Catman chart in which the membrane pressure (and perhaps the pore pressure) can be monitored. (CatModules →Measuring→Data logger)
5. Start recording.
6. Turn on the vacuum pump and regulate until the wanted suction level is displayed in the manometer.





7. Apply pressure to the tube under the pile flange gradually as the suction on the membrane increases.
8. The setup is left over night, as it takes some hours for the suction to reach the wanted pressure level and remain stable.
9. When the suction level is stable stop the measurements in Catman but do not reset the pressure transducers.

6 Static Pile Testing

To run a test, either displacement or load controlled, the program MOOG is used. The measurements from the tests (displacements, loads, pore pressures, atmospheric pressure, suction on membrane) are collected by means the program Catman placed on a different computer which is connected to Spider 8 and MGCplus.

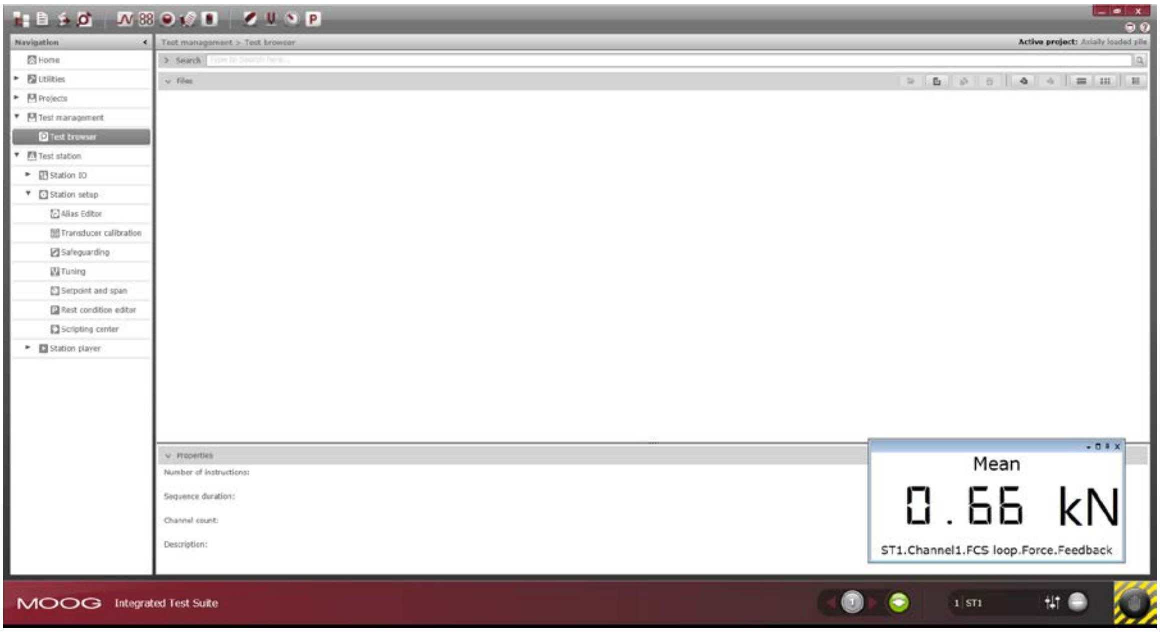
6.1 Test Sequence in MOOG

The test is a static test which is run at a velocity of 0.002 mm/s to ensure drained conditions during test. The end position is chosen as 50 mm.

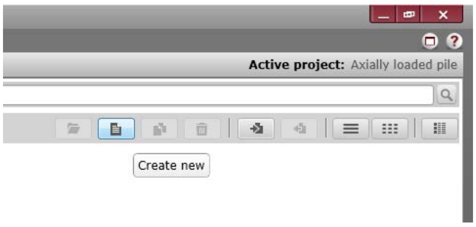
Create a new test sequence in MOOG or reload and existing load sequence.

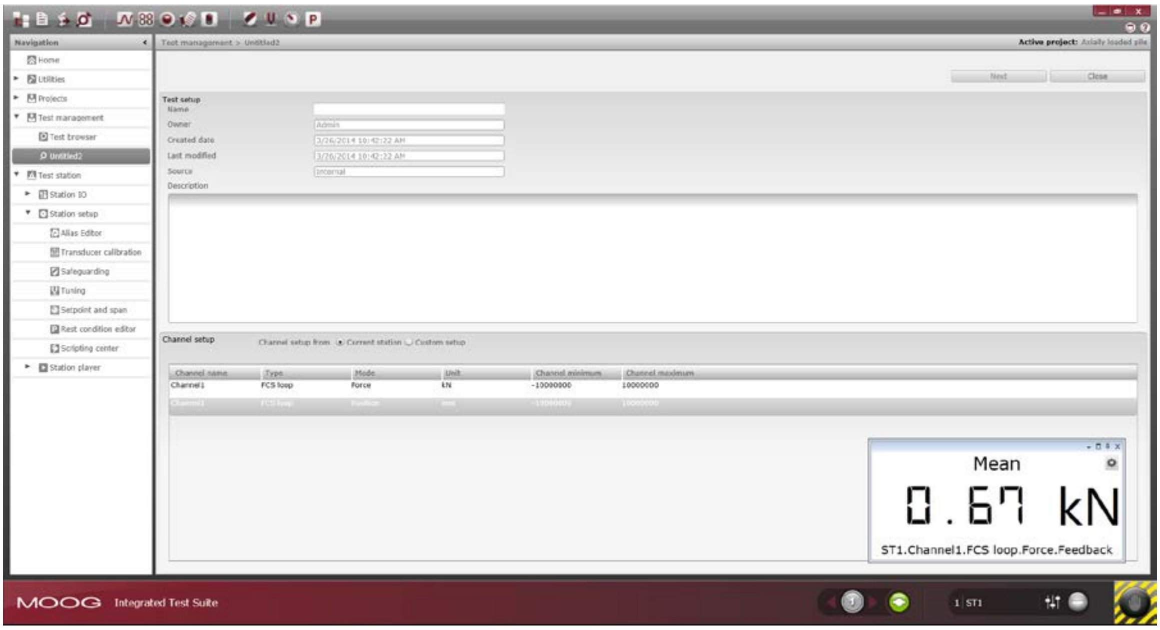
Creating a new test sequence.

1. Press “Test management” and “Test browser” in the Navigation tool bar.

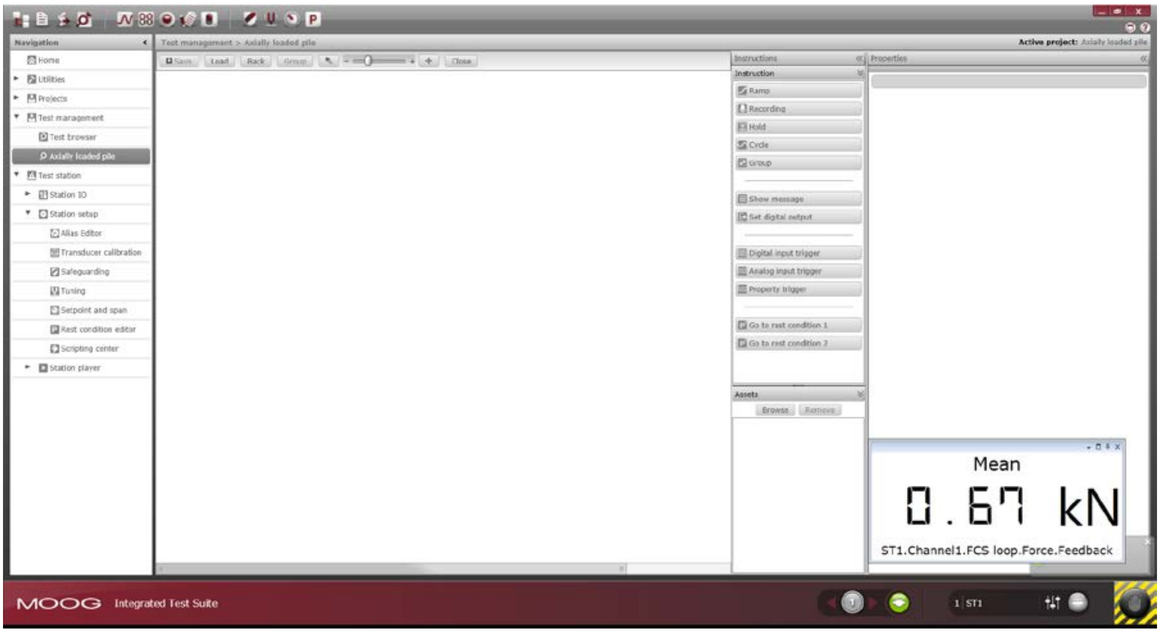


2. Choose “Create new” to the right in the toolbar.

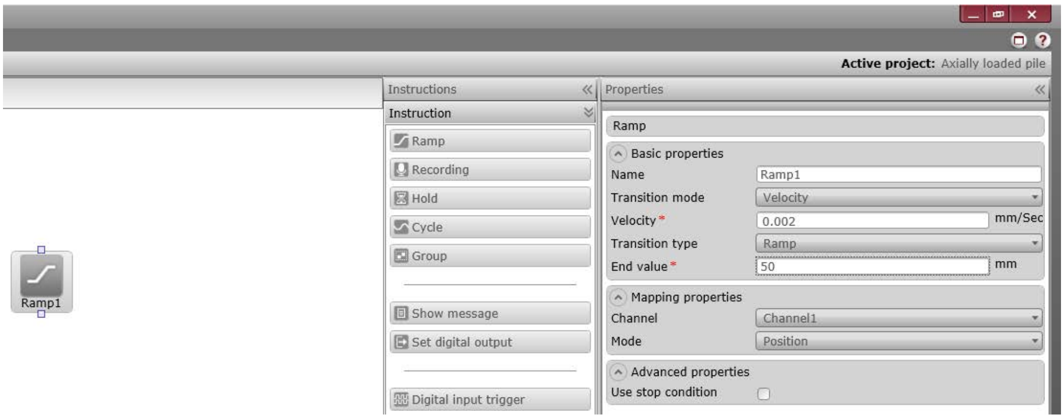




3. Write a project name and press Next.



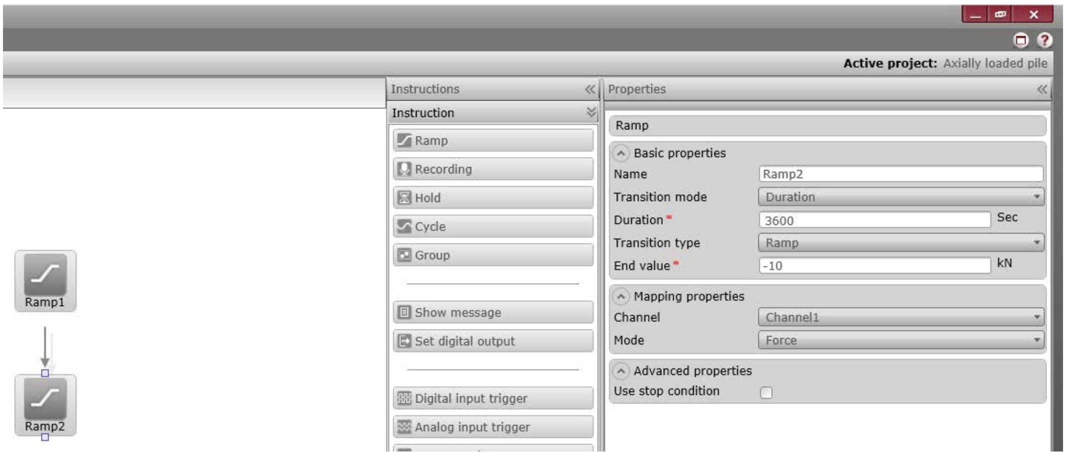
4. Drag a "Ramp" to the canvas from the Instruction menu.
    - Name: Choose a name or just leave it as Ramp1
    - Transition mode: Velocity
    - Velocity: The speed at which the test should run
    - Transition type: Ramp
    - End value: The end value is the end position of the hydraulic cylinder. If the pile should move 50 mm upwards, 57 mm is given here, because of bending of the test setup. The setpoint given in "Setpoint and span" is the point of zero displacement.
    - Channel: Channel1
    - Mode: Position
    - Use stop condition: (do not tick off)



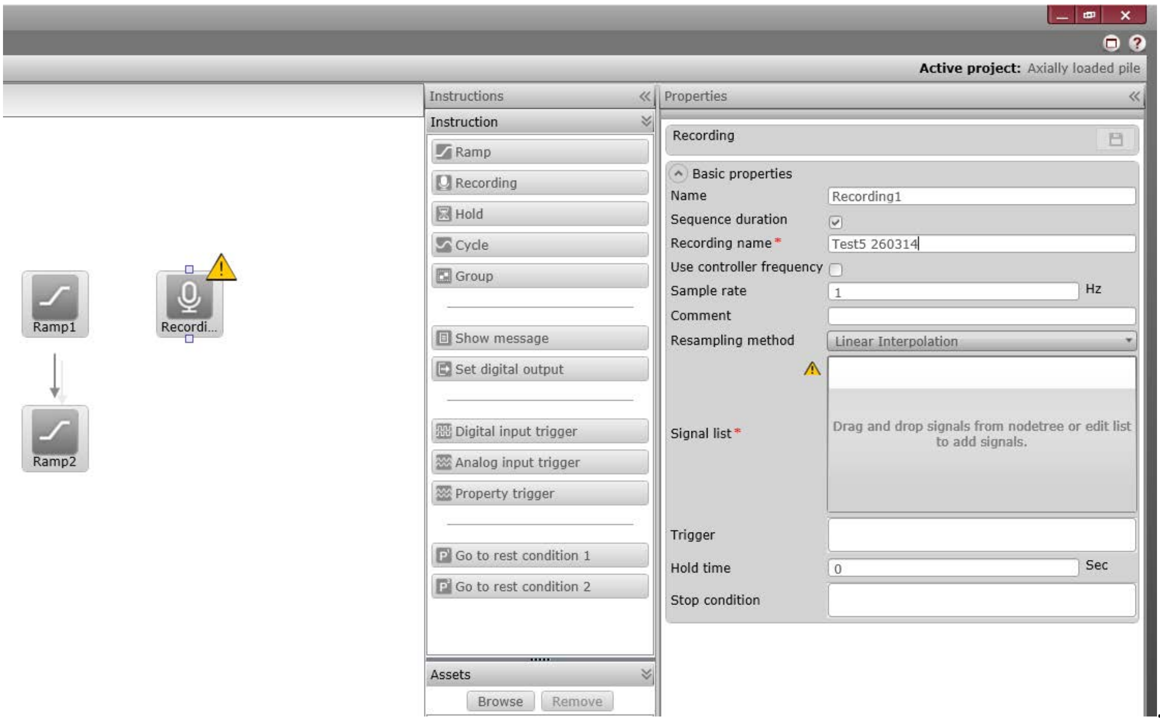
5. Drag a new "Ramp" to the canvas and place it underneath the first ramp. This means that the new ramp will follow the first ramp in time. The second ramp is used to bring the hydraulic cylinder into a wanted end-position. If no ramp is made, the MOOG system will force the cylinder into its starting position within a second. Two things are not desirable in this scenario: Firstly, the it will result in a very large force in a very limited amount of time; secondly, if the test is run over night the system can be left pressing the pile with really high force for a long period of time, which is not

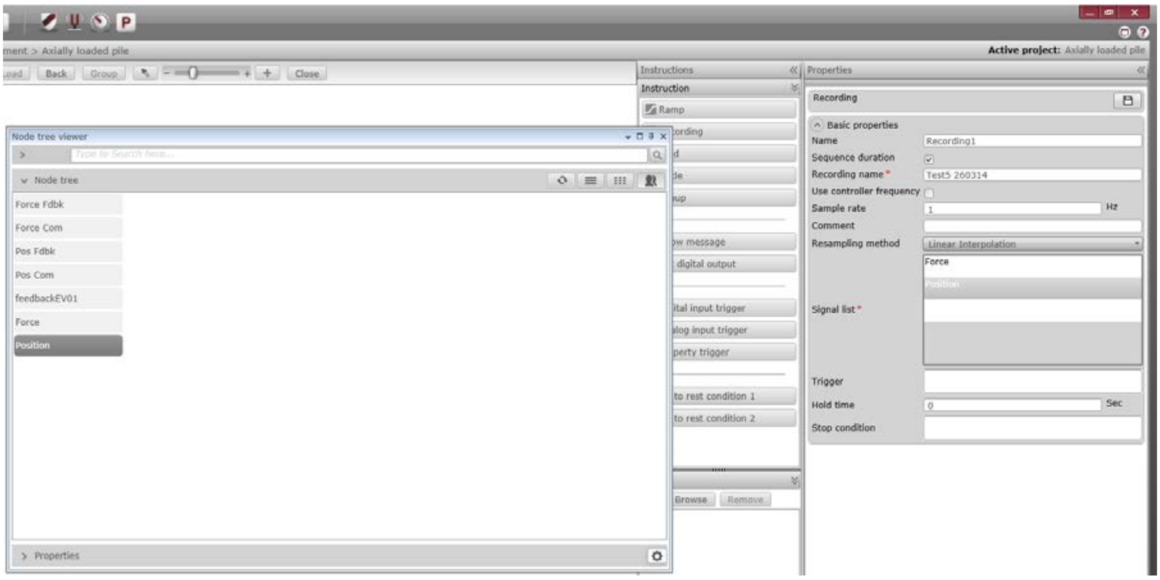
good. Therefore, it is chosen to make the system end in a position where the force on the pile is rather small (e.g. 0kN) over a period of an hour. In the menu to the right give the following values.

- Name: (Choose a name or just leave it as Ramp2)
- Transition mode: Duration
- Velocity: The time the ramp should take
- Transition type: Ramp
- End value: The wanted end force on the pile
- Channel: Channel1
- Mode: Force
- Use stop condition: (do not tick off)

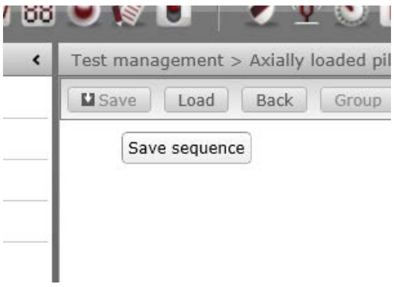


6. Data from the test is recorded by dragging a “Recording” into the canvas and placing it next to “Ramp1”. Tick off “Sequence duration” meaning that the data will be recorded throughout the test including Ramp2. Drag “Force” and “Position” from “Node tree viewer” into the signal list to obtain data on the force and the displacement during tests.





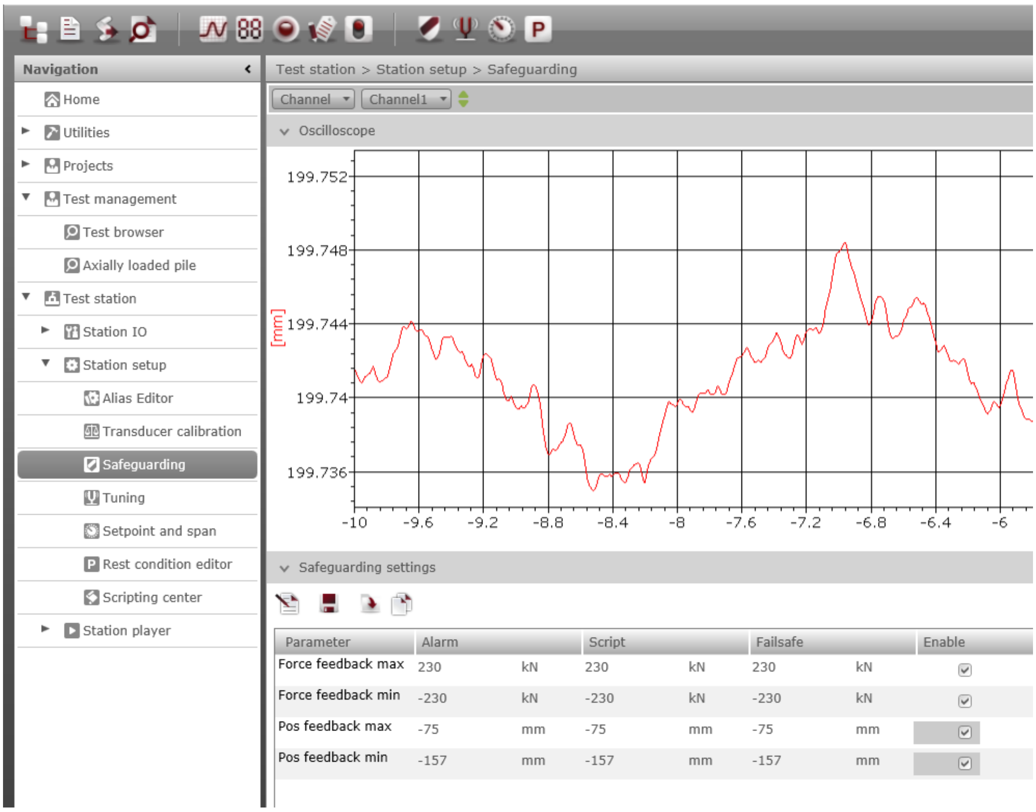
7. Save the sequence by pressing “Save sequence”.



It is also possible to load a previously saved load sequence.

1. Choose Test browser and open Data sampling.

Before starting the test it is important to set the safeguarding. When connecting hydraulic cylinder 2 to the pile only the max and min values of the forces (-230 – 230 kN) is active. However, to protect the equipment during a test maximum and minimum values of the displacement are given as well. The values here are determined based on the position given in “Setpoint and span”, which is not considered to be the zero position as when making the test sequence. This means that if the setpoint in “Setpoint and span” is -62 mm and the wanted displacement is +50 mm, then the safeguarding could be set as min = -67 mm and max = -7 mm. It is important to check the test setup to see, if anything can break within the safeguarding limits (check the span of the external displacement transducers, will the pile hit anything in the outer positions). If the limits are chosen too close to the settings in the test sequence. The program may introduce an emergency stop before the test is finished, if the limits are too close to the test settings, in which case none of the recorded data will be saved. Choosing the limits 5 mm above the End value in the test sequence and 5 mm below the setpoint in “Setpoint and span” will do. If the safeguarding values are changed, remember to change the value in all the columns (“Alarm”, “Script”, and “Failsafe”). The values are not changed until Enter is pressed.



6.2 Data Acquisition in Catman

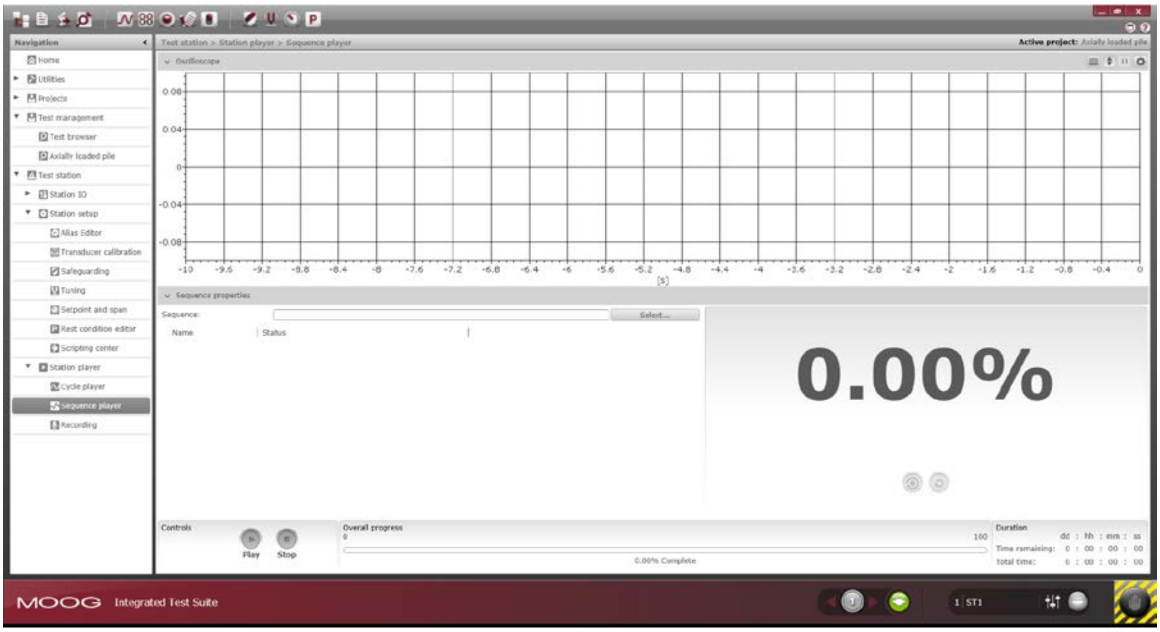
Check that the pore pressure transducers are the same as the once in the file otherwise new calibration factors should be found for the specific transducer.

1. Catman is started (same procedure as in Sec. 5.2).
2. Load the appropriate I/O-file for the MGCplus during tests.
3. If the test is one without membrane, all the transducers are reset. If the test is one with membrane the pore pressure, membrane transducer and atmospheric pressure transducer is not reset.
4. Make a Catman chart in which the wanted measurements can be monitored. (CatModules →Measuring→Data logger)
5. Start recording.

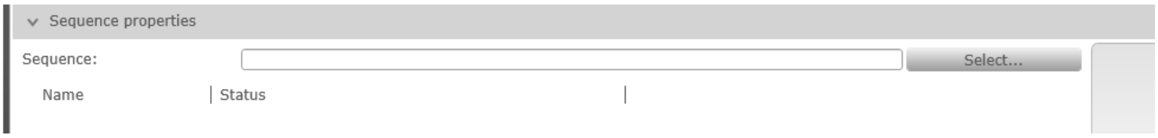
6.3 Run Test

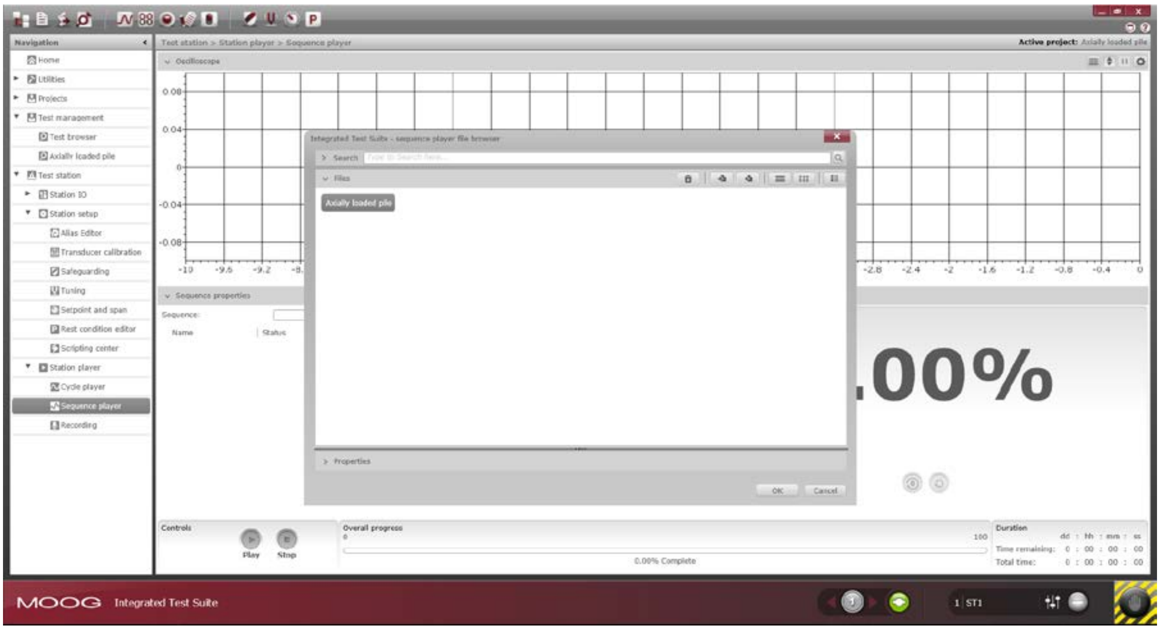
When the test sequence is made in MOOG and the Catman is started, the test is ready to run.

1. Click “Station Player” and thereafter “Sequence player”



2. Select the sequence to be run





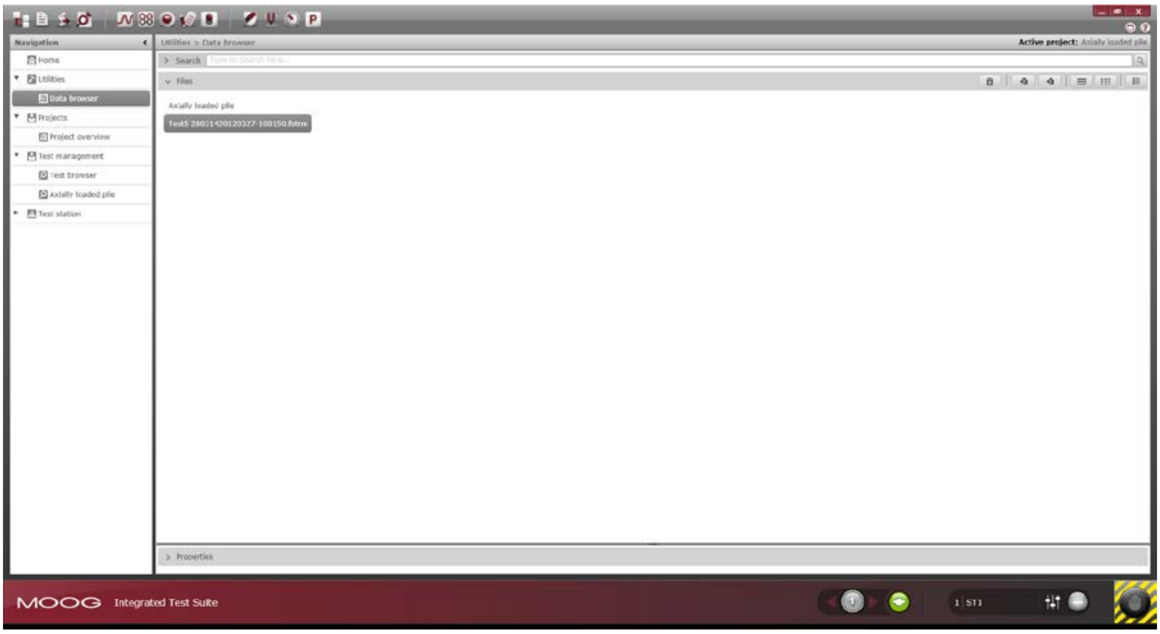
3. Press “Play”.

4. Be aware that the percentage shown in large numbers is not an indicator of how advanced the test is. This can be seen in the green bars.

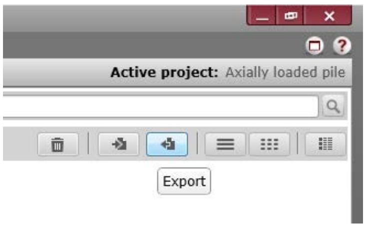
6.4 Save Data

When the test is finished, the results from MOOG is saved.

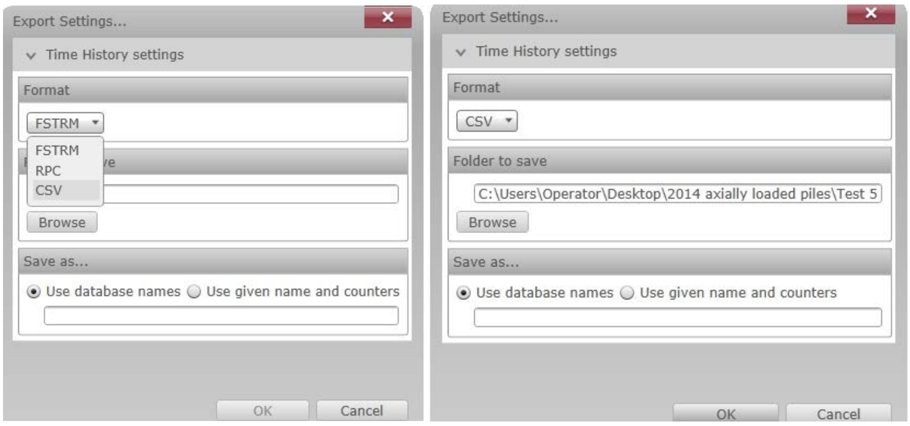
1. Press “Utilities” and “Data browser”.



2. Choose the file you want to save and press “Export” in the upper right corner.



3. Choose CSV format and the folder direction in which to save the data files.



Saving results in Catman

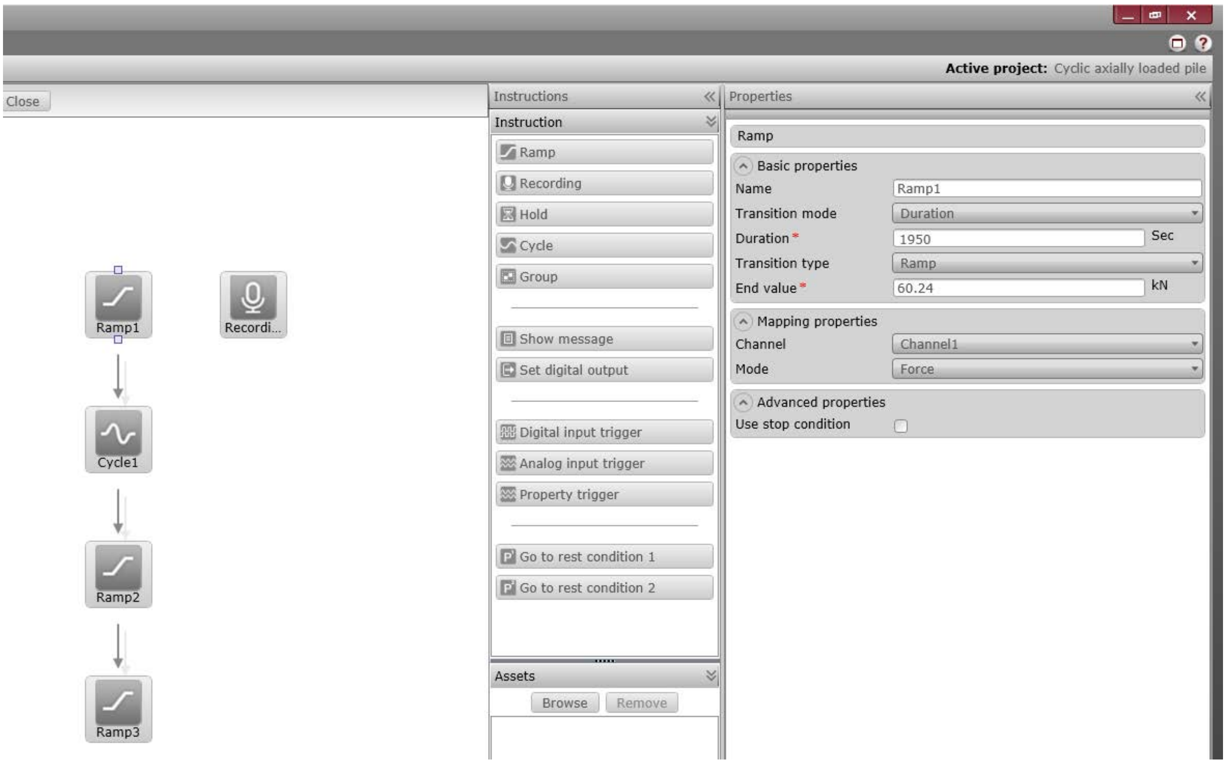
1. Stop data acquisition in Catman and save the appropriate channels, cf. Sec. 4.3.

7 Cyclic Loading

7.1 Test Sequence in MOOG

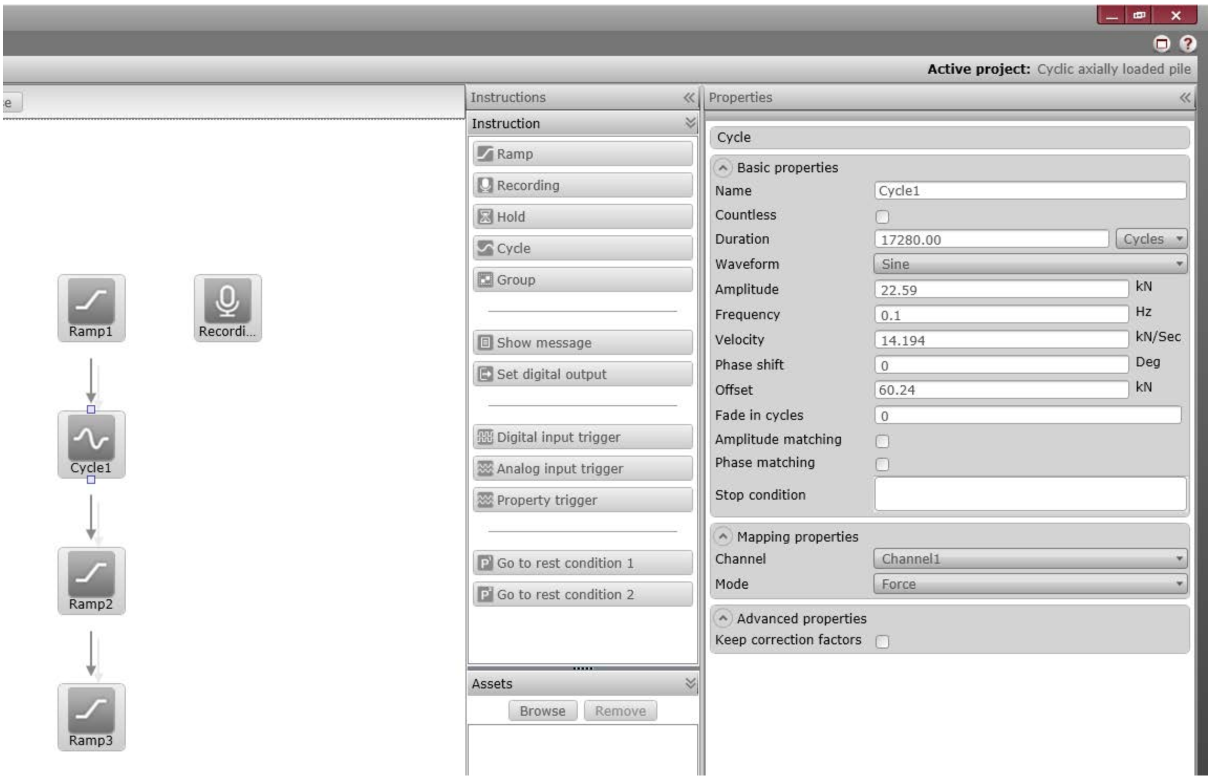
Create a new sequence by following bullet 1–3 in Sec. 6.1 or load an existing test sequence.

1. Ramp1 is a force controlled part where the wanted mean load of the subsequent cyclic loading is reached.
    - Name: Choose a name or just leave it as Ramp1
    - Transition mode: Duration
    - Duration: The duration is chosen based on how long it took to reach the load chosen in "End value" in the corresponding static test
    - Transition type: Ramp
    - End value: Wanted mean load of the subsequent cyclic loading. This value is added to the
    - Channel: Channel1
    - Mode: Force
    - Use stop condition: (do not tick off)

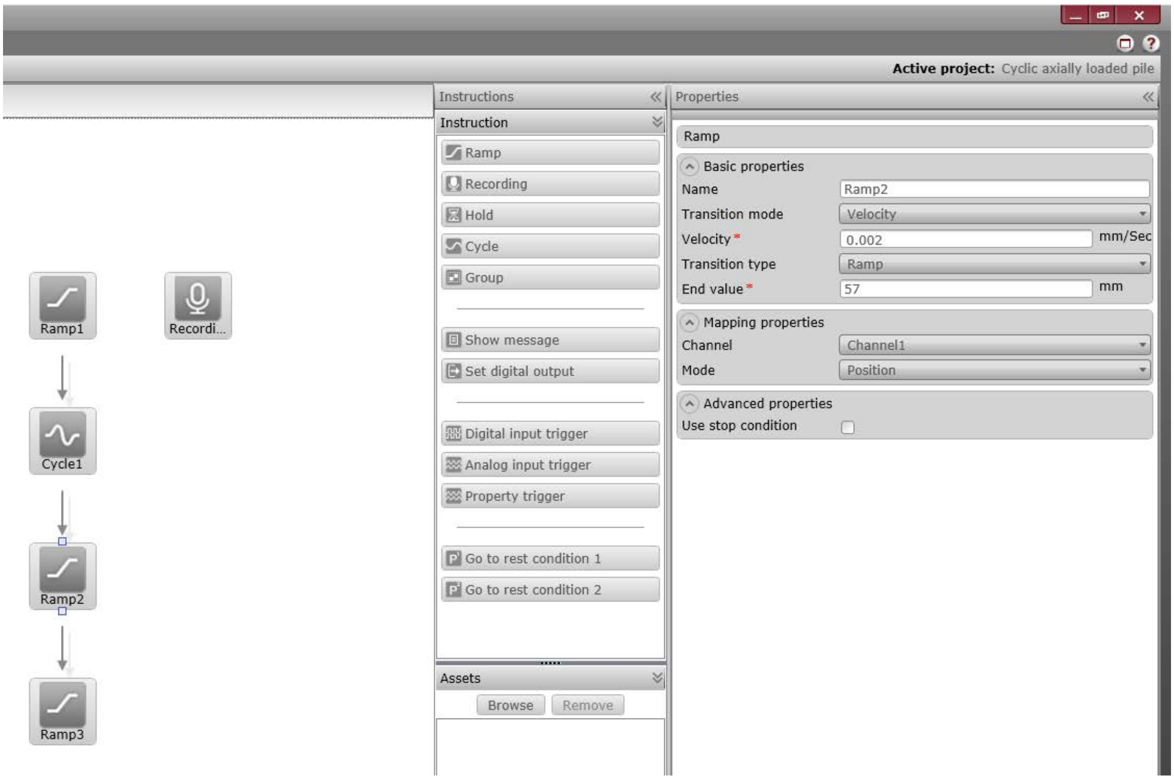


2. Cycle1 is the cyclic loading sequence
    - Name: Choose a name or just leave it as Ramp1
    - Countless: (Do not tick off)
    - Duration: Wanted number of cycles
    - Wave form: Sine
    - Amplitude: Wanted amplitude
    - Frequency: 0.1 Hz
    - Velocity: (MOOG calculates this value itself from amplitude and frequency)
    - Face shift: 0 Deg
    - Offset: The wanted mean load (corresponds to end value of Ramp1)
    - Fade in cycles: 0
    - Amplitude matching: (Do not tick off)
    - Face matching: (Do not tick off)

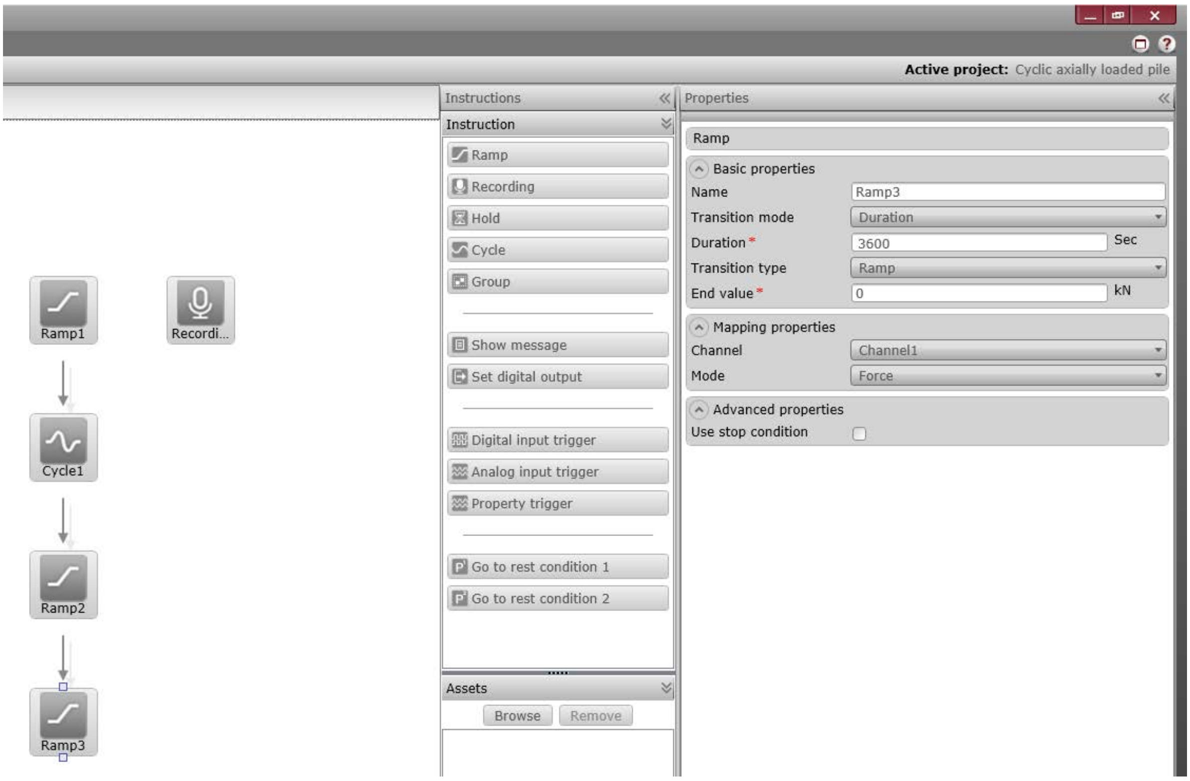
- Stop condition: (Leave empty)
- Channel: Channel1
- Mode: Force
- Keep correction factors: (Do not tick off)



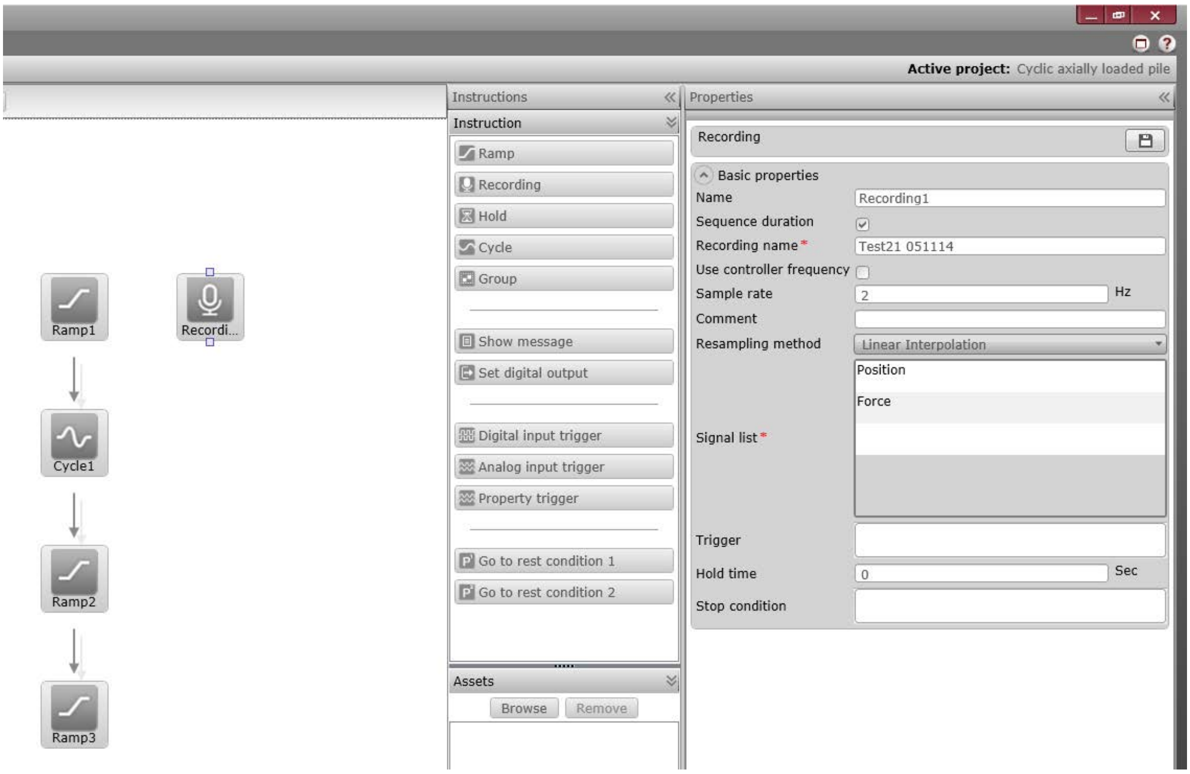
3. Ramp2 is a displacement controlled part where a total pile displacement of 50 mm (inclusive the displacement reached in Ramp1 and Cycle1) is reached.
    - Name: Choose a name or just leave it as Ramp2
    - Transition mode: Velocity
    - Duration: 0.002 mm/s
    - Transition type: Ramp
    - End value: 57 mm is inserted to get an actual pile displacement of 50 mm.
    - Channel: Channel1
    - Mode: Position
    - Use stop condition: (do not tick off)



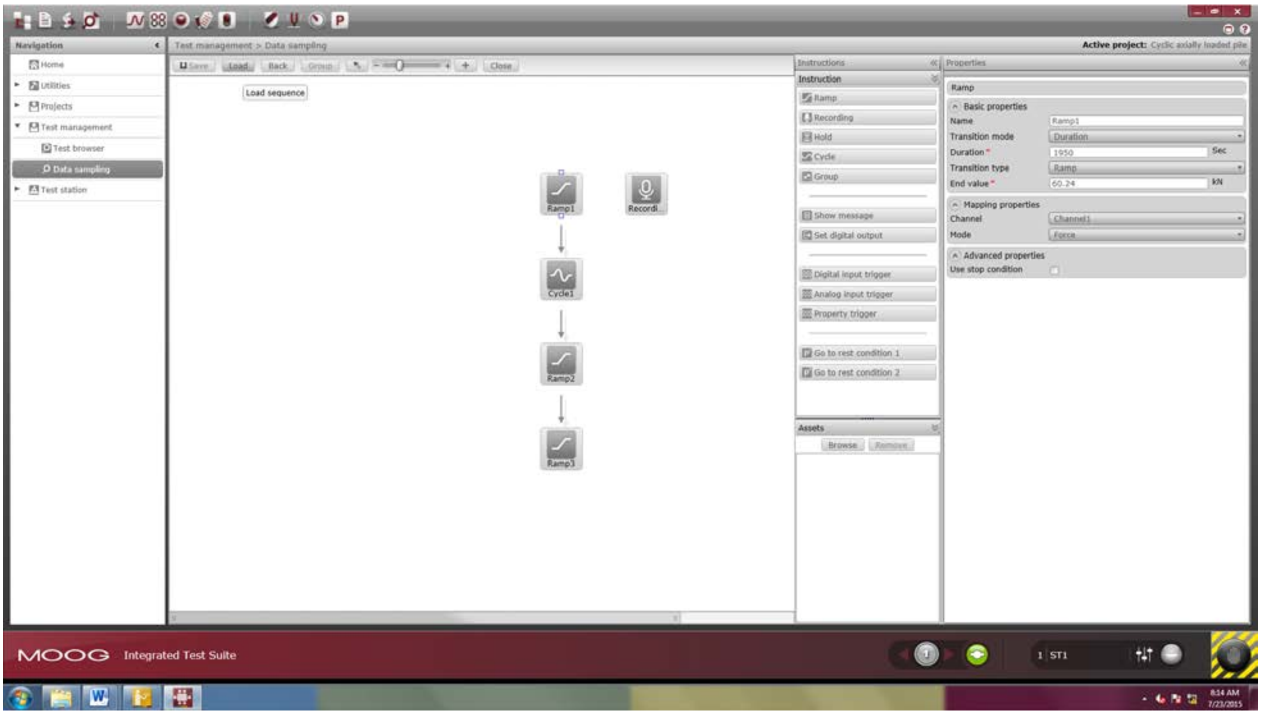
4. Ramp3 is a force controlled part where the wanted end load is reached.
    - Name: Choose a name or just leave it as Ramp3
    - Transition mode: Duration
    - Duration: 3600 s
    - Transition type: Ramp
    - End value: 0 kN
    - Channel: Channel1
    - Mode: Force
    - Use stop condition: (do not tick off)



5. Data from the test is recorded by dragging a “Recording” into the canvas and placing it next to “Ramp1”. Tick off “Sequence duration” meaning that the data will be recorded throughout the test including Cycle1, Ramp2 and Ramp3. Drag “Force” and “Position” from “Node tree viewer” into the signal list to obtain data on the force and the displacement during tests.



6. Press “Load sequence” and the test sequence is ready to be run.

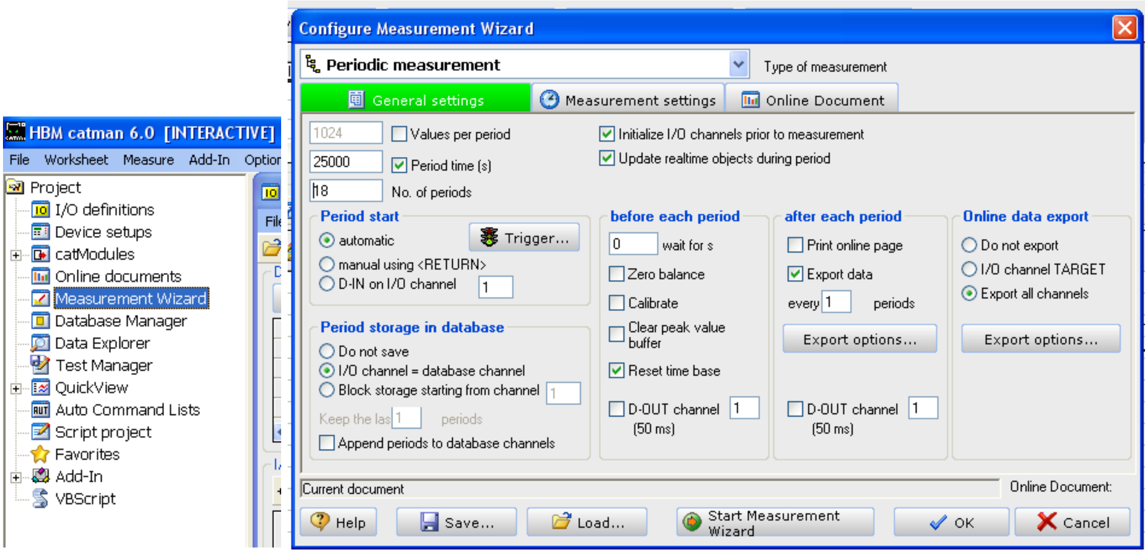


7.2 Data Acquisition in Catman

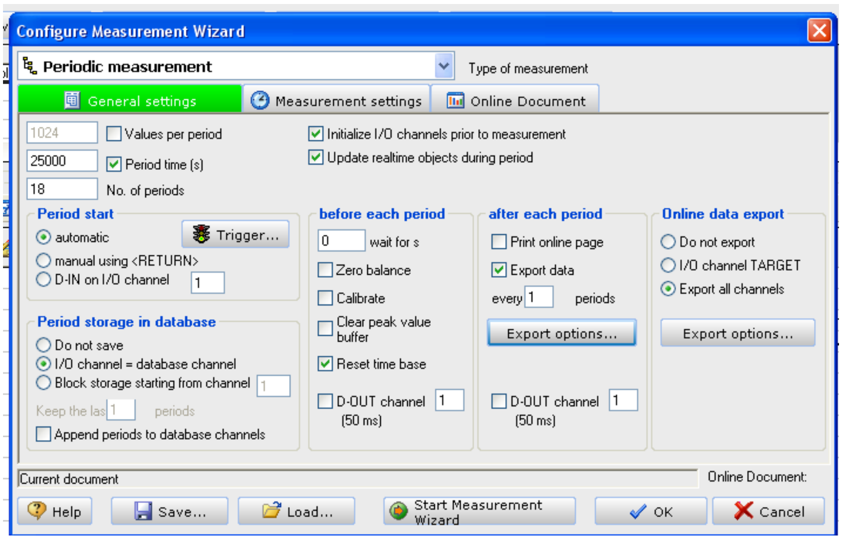
Start Catman in the same way as for static tests. Reset all the transducer (except for the pore pressure, membrane pressure, and atmospheric pressure it the test is one with membrane.

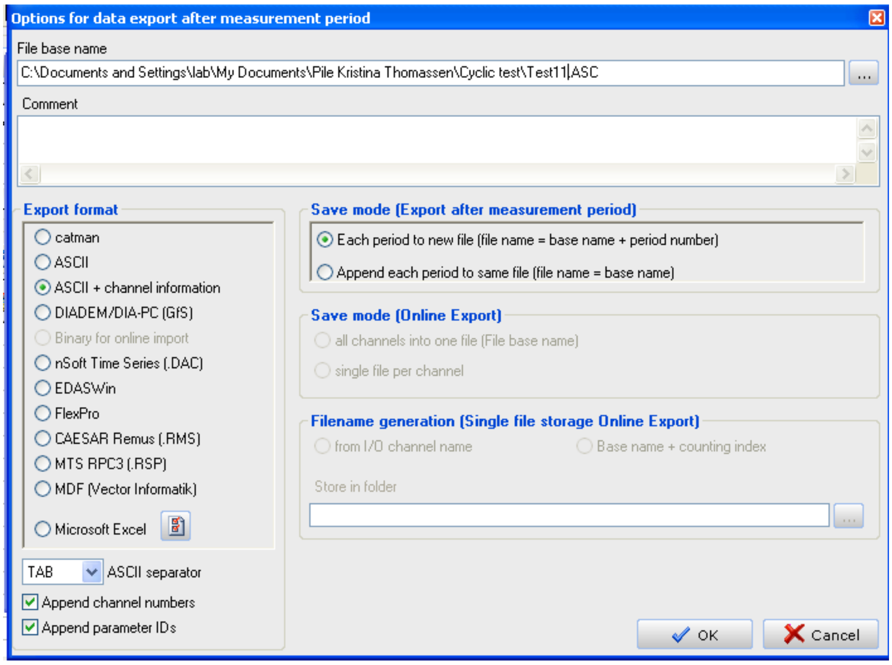
The cyclic loading tests are much longer than the static tests and the amount of recorded data is accordingly large. If using the data logger for recording of the measurements with a sample rate of 2 Hz, the file gets too large and Catman eventually stops recording. Thus, much data can get lost and data acquisition for cyclic tests should instead be done by letting Catman save a number of files automatically during the tests.

1. Open the measurement wizard.
2. Insert a period of time for which the data files do not get too large and makes Catman stop.
3. Choose number of periods for saving. Thus, choosing 18 as in the example means, that Catman will save 18 files all containing data of 25000 s if the data recording is not stopped before the time (18*25000 s) is elapsed.

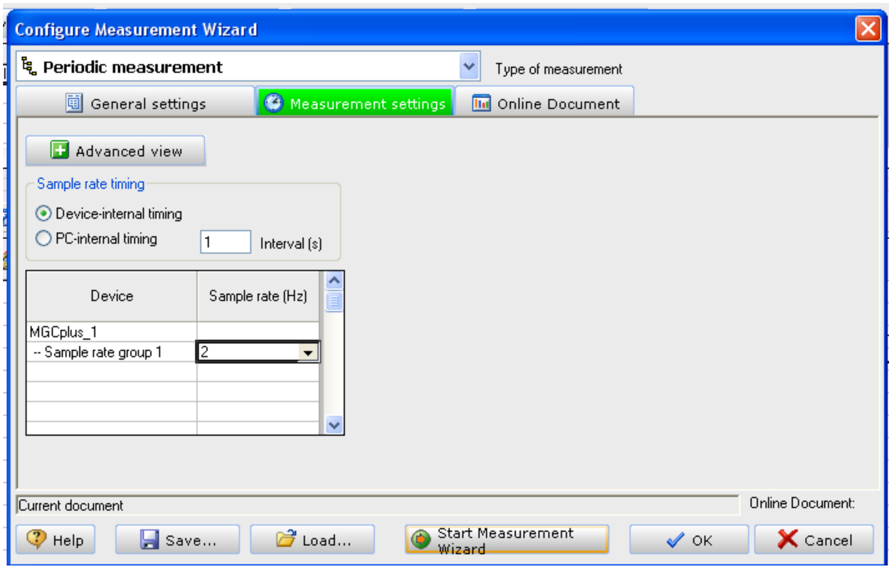


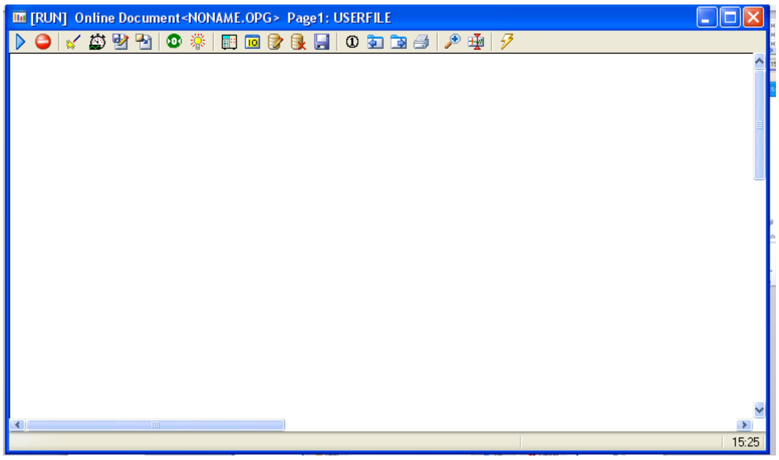
4. Open Export options.
5. Type in an appropriate folder direction and file name and choose the export format ASCII-channel information as well as TAB (Tab delimited file).
6. Press ok.



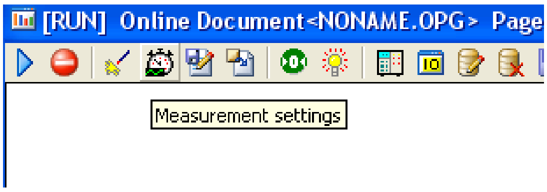


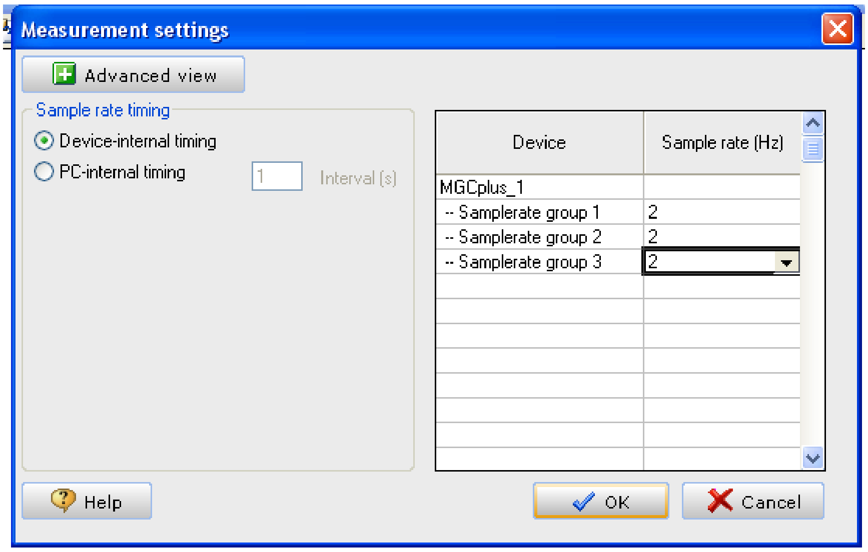
7. Open Measurement settings and set the Sample rate to 2 Hz.
8. Press Start Measurement Wizard.



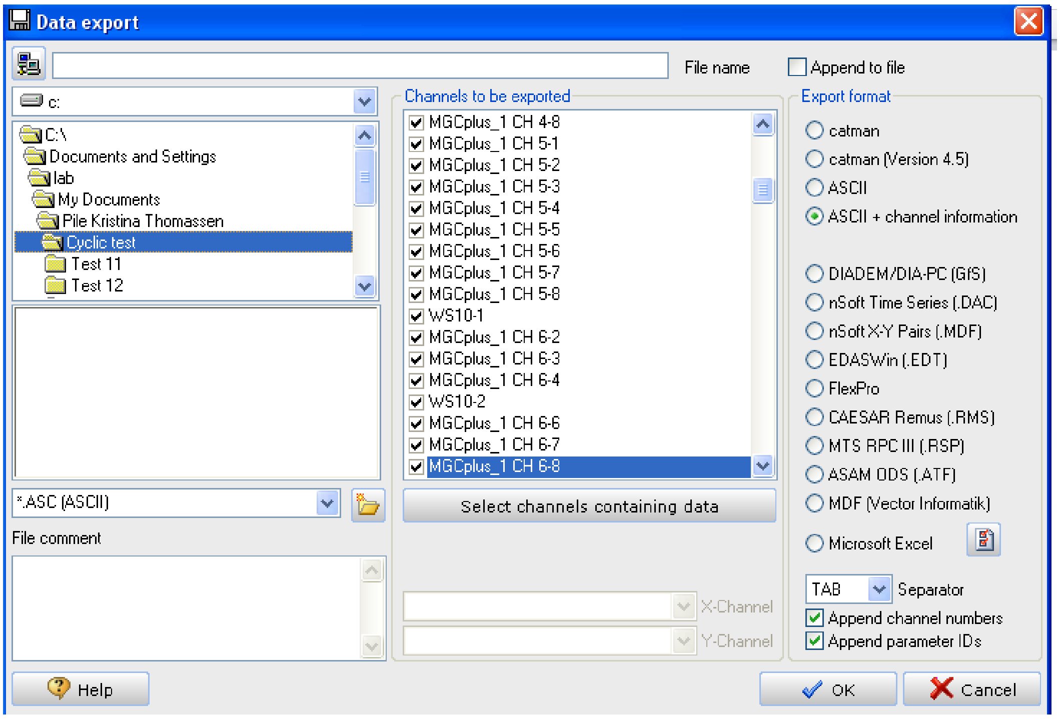


9. Check the sampling rate





10. Choose the channels to be exported.



7.3 Run Test

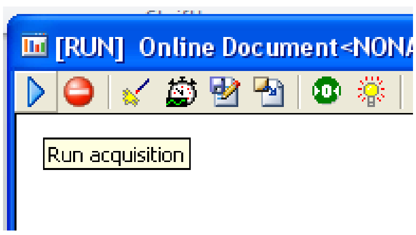
Prior to running the test it is important that the force on the pile is 0 kN to reach the correct mean value for the cyclic loading test.

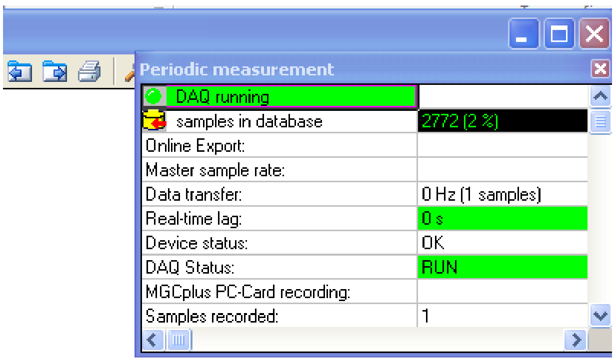
1. Use "Setpoint and Span" to reach 0 kN. Use a very low rate [kN/s] to avoid any large disturbance of the soil.

It is also important that the recording time in Catman and MOOG are exactly the same, to get a Catman data file with corresponding measurements of the pile displacement and the load. (This problem is not solved at the time of writing).

To start the test in MooG , the same procedure as for static tests described in Sec. 6.3 is followed.

To start the test in Catman, press the blue triangle.





7.4 Save Data

To save the MooG data, the same procedure as described in Sec. 6.4. The Catman data is automatically saved when the data acquisition is stopped.

8 Uninstallation of the Pile

The bar with displacement transducers is removed.

Hydraulic cylinder 2 is disconnected from the pile.

1. The bolts keeping the pile and the transition piece together are removed.
2. The displacement safeguarding should be removed before hydraulic cylinder 2 is moved upwards. Otherwise, the displacement will be larger than the ones given in the safe guarding, and this will result in an emergency stop.
1. Hydraulic cylinder 2 is moved upwards till the highest possible position (200 mm). “Setpoint and span” is used. Check that the mode is in “Position” and not “Force”.
2. Turn off the hydraulics.
3. The load cell and the MOOG displacement transducer are disconnected.
4. Hydraulic cylinder 2 is moved to the left side of the load beam after removing the bolts holding it in place on the load frame.

Hydraulic cylinder 1 is connected to the pile.

1. Hydraulic cylinder 1 is moved to the middle of load beam and the eight bolts are placed in the holes – do not tighten the nuts yet.
2. The pile is connected to transition piece 2.
3. Tighten the eight nuts.

8.1 For Tests without membrane

The pile is uninstalled.

1. If desired, the displacement, load and pore pressure can be measured during uninstallation as well. The load cell is connected to Spider8, and the measurements are recorded in Catman.
2. The uninstallation rate is chosen as 0.35 mm/s.

The pile is removed from the sand box.

1. The footbridges are moved underneath the pile
2. The pile is lowered until it is supported by the footbridges. Be careful not to press it too hard against the footbridge.
3. The pile is disconnected from the transition piece and moved to the edge of the footbridges.
4. The transition piece with an eye is connected to the pile lid so the crane can be connected to the pile top
5. The pile is placed on the pallet next to the water reservoir used when saturating the pore pressure transducers.

8.2 For Tests with Membrane

Let the pressure out of the tube under the pile flange:

1. Close valve to the compressor.
2. Let air out of the manometer.
3. Remove the tube from the quick-coupling inside the pile.

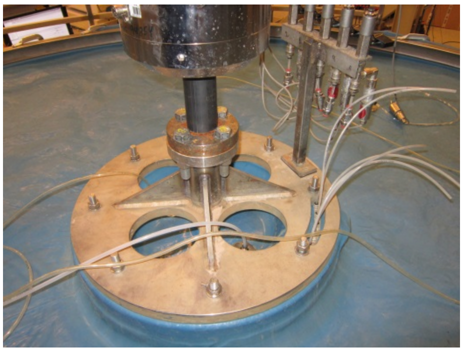
Stop the suction on the membrane.

1. Stop the vacuum pump.

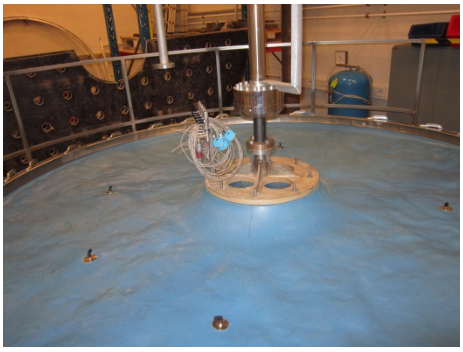
2. Remove the hose connected to the tube under the pile lid.
3. Remove the suction tubes from the membrane.
4. Empty the water tank connected to the vacuum system by connecting a hose to the bottom outlet and opening the valve.


Remove the pile lid

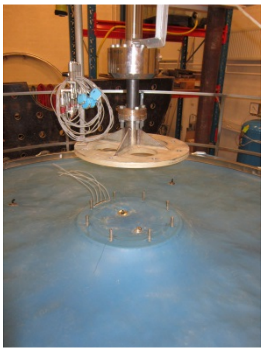
1. Disconnect the hoses to the pore pressure transducers.



2. Loosen and remove the eight nuts connecting the pile lid to the pile.

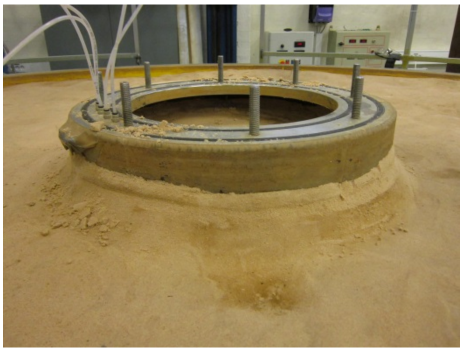



3. Lift the pile lid by means of the hydraulics and leave it hanging in the air.



Remove the membrane

1. Remove the clamps fastening the aluminium frame to the edge of the sand box.
2. Remove the aluminium frame (job for two people).
3. Remove the black rubber ring, the membrane, the felt cloth, the tube under the pile lid, and the rubber ring in the groove in the sand box edge.



Measure the water level in the sand box. This water level is assumed to be the water level present during the entire test.

1. Open the valve to the ascension pipe at the bottom of the sand box.
2. Measure the water level as the distance from the sand surface to the water head in the ascension pipe.

Placing the other aluminium ring

1. Clean the sand box edge with paper and compressor and place the black, squared rubber ring in groove in the sand box edge.
2. Place the other aluminium ring on the sand box edge (job for two people).
3. Place the two aluminium bars (nr. 7 and 8)
4. Place the footbridges crosswise on the aluminium bars.

Saturate the sand

1. Open the valve letting water into the sand box, the gradient should not exceed 0.9, which in the beginning is a much lower water head in the ascension pipe, than used prior to installation.

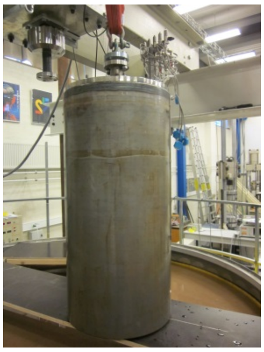
The pile is uninstalled.

1. Clean the pile flange with the compressor and fasten the pile lid to the pile flange.
2. Use the hydraulics to uninstall the pile, while a gradient of 0.9 is still applied.
3. If desired, the displacement, load and pore pressure can be measured during uninstallation as well. The load cell is connected to the Spider 8, and the measurements are recorded in Catman.



The pile is removed from the sand box.

1. The footbridges are moved underneath the pile
2. The pile is lowered until it is supported by the footbridges. Be careful not to press it too hard against the footbridge.
3. The pile is disconnected from the transition piece and moved to the edge of the footbridges so the crane can be connected to the pile top and the pile moved to the floor.



9 Bibliography

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Vaitkunaite, Evelina, Kristina Thomassen, Kim Borup, and Benjaminn Nordahl Nielsen. *Safety Instructions in the AAU Gaotechnical Laboratory - Large Yellow Box.* DCE Technical Report No. 197, Aalborg University, 2015.

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