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by

Evelina Vaitkunaite

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Contents

1. Objective

This is a practical guide for preparing the soil, running a CPT test, installing a scaled bucket foundation model and running a test in the large yellow sand box *cos(Kristina)* in the geotechnical laboratory at Aalborg University. The test procedure is used for the examination of statically and cyclically axially loaded bucket foundation model in dense sand. The foundation model in scale of approximately 1:10 compared to the prototype size. The guide describes the step-by-step procedure for tests with and without surface pressure. A detailed description of test setup using the large yellow sand box for a monopile testing was provided by Thomassen (2015a), procedure for monopile testing can be found in Thomassen (2015b), while safety instructions were given by Vaitkunaite et al. (2014).

Figure 1. The large yellow sand box *cos(Kristina).*

2. Safety First

The following tables provide a short overview of the main safety tools and recommendations according to Vaitkunaite et al. (2014).

Table 1. Safety equipment.

Equipment	Action
Safety shoes	To wear all the time.
Helmet	To wear when working directly with the testing rig, sand box and operating the crane.
Safety sling	To wear when standing on the sand box edge, fastening the hydraulic cylinders, climbing on the top of the testing rig.
Earmuffs/Earplugs	To wear when vibrating
Vibration gloves	To wear when vibrating
Gloves	Recommended to wear as protection against splinters or the like
Knee protections	Recommended to wear when vibrating

Table 2. Safety rules.

Procedure	Equipment required / recommended	Comment
Loosening the sand	Safety shoes / Gloves.	
Vibrating	Safety shoes, vibration gloves, helmet, earmuffs or earplugs / Knee protections, safety sling.	1h of vibration is followed by 1h of other type work.
CPT testing	Safety shoes, helmet / Gloves, safety slings.	
Fastening hydraulic cylinders	Safety shoes, helmet, safety slings / Gloves.	
Operating the crane	Safety shoes, helmet / Gloves.	
Working with the MOOG system	-	Body parts, such as hands and fingers, can never be under the MOOG cylinder when the pressure is "HIGH".
Lifting heavy equipment	-	If the crane cannot be used, ask some of the laboratory staff for help with lifting, holding etc.
Working on the sand box	Safety shoes, helmet / Gloves.	Both of the safety enclosures must be closed.

3. Test Set-up

The following two figures are taken from Vaitkunaite et al. (2015).

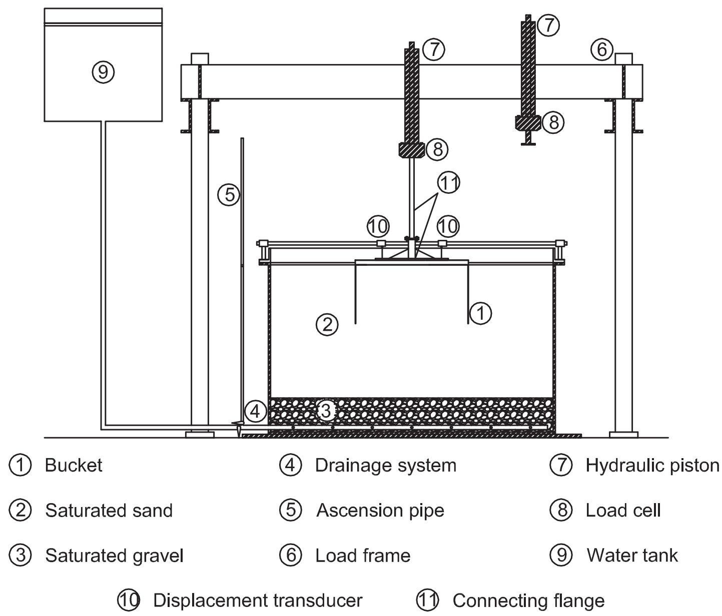


Figure 2. Test set-up drawing after Thomassen et al. (2015c).

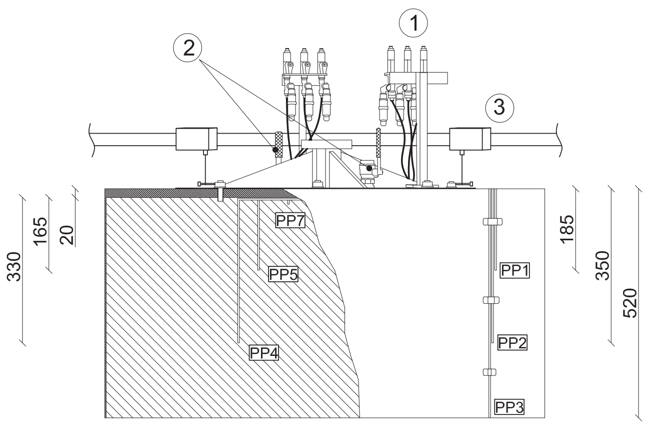


Figure 3. Bucket model drawing, given dimensions in mm: pressure transducer (1); valves (2); displacement transducers (3); positions for the pore pressure measurements (PP1-PP7).

4. Preparation of the Sand

Uniform sand compaction to high density ratio of approx. 80% is ensured by mechanical vibration with a rod vibrator. Prior to each test the soil is loosened by an upward gradient of 0.9 applied through the drainage system in the bottom of the sand container. An aluminium frame is mounted on the top of the container to retain the water due to the level raise. Previous testing, e.g., Larsen

(2008), has shown that this preparation method can ensure stable and comparable conditions in the soil.

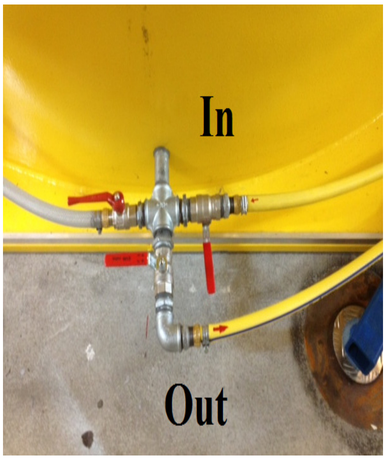
4.1 Adding sand if needed

Sand compaction lowers the level of sand, if it can be expected that the level will be too low, some additional sand can be poured before starting step 4.2.

4.2 Loosening sand with gradient

1. Ensured that the water tank is full. Make sure to close water valve (In) to the yellow box before filling the water tank. When the water tank is full stop pouring the water to it.

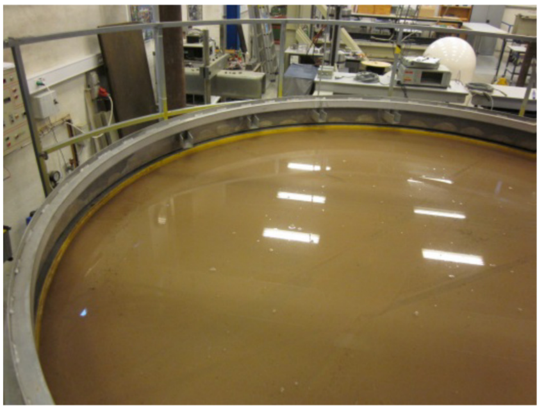




2. Use the air-piston to blow all the sand away from the small groove in the frame. Be aware not to blow sand in to any electronic devices. Use some paper to wipe the edge of the box after using the air piston. Ensure a clean surface for mounting the aluminium frame.

3. A large rubber O-ring is washed and wiped with a towel. Afterwards it is placed in the groove to ensure a tight connection. Make sure that it fits evenly all the way around.


4. Place the aluminium frame on the sand box and make sure the rubber ring is correctly positioned. The ring position is marked on the sand box and the aluminium frame with numbers from 1 to 4. Fix the frame with clamps.

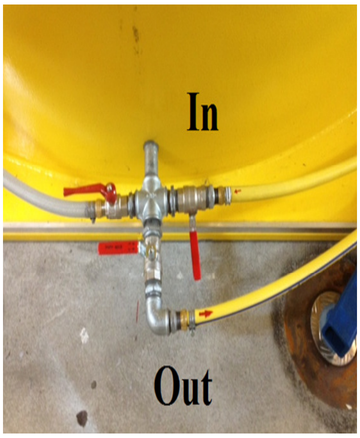



5. Open the valve “In”. A hydraulic gradient, i, of 0.9 should be used for loosening the sand. Thus choose a pressure difference, which satisfies the criterion:

   $i = \frac{\Delta h}{H} \Rightarrow \qquad \Delta h = i \cdot H = 0.9\,H,$

   Where: H is the thickness of the sand in the container (1.20 m); Δh is the pressure difference in pressure head. (1.08 m)

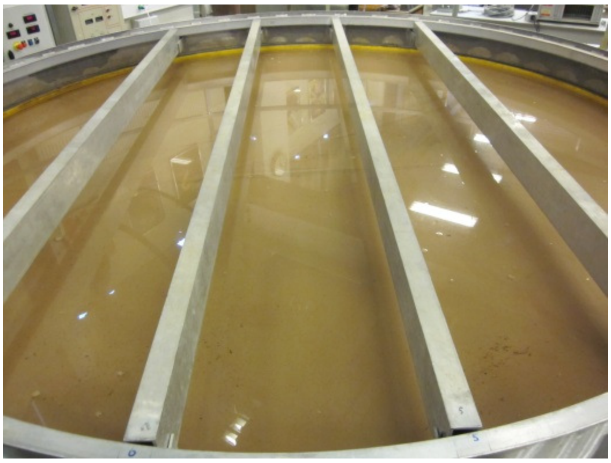
The gradient should be applied for at least 5 min. (Water raises up by 6 cm in 20 min)



6. The water level should be 5-8 cm above the soil surface.

4.3 Vibration

1. Place four aluminium beams in the frame. The bars and their positions are numbered.



2. Then the wooden plates with holes for the rod vibrator are placed on top of the bars. Each of the plates should be adjusted to positions on the aluminium ring (grooves I and II) which ensures that no hole is blocked by the aluminium supporting beams.

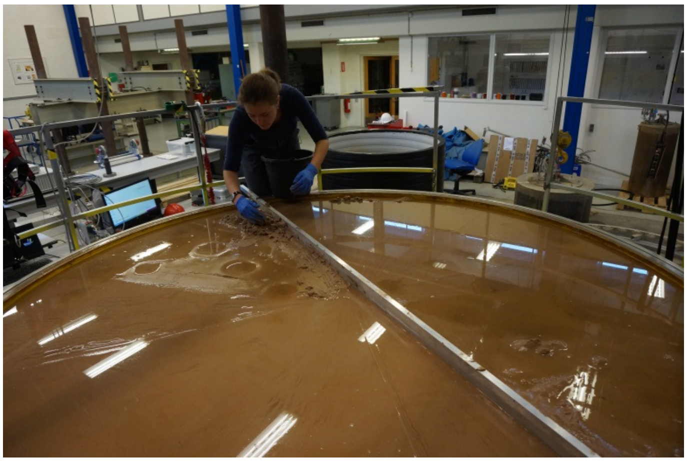
3. Always use special gloves when vibrating. They help neutralize the vibration from the rod. Helmet is needed when working under the metal beams.

4. To ensure a uniform compaction of the soil the vibration: It is important to use the same speed down and up the holes. It is needed to force the rod on the way down. If it feels like the rod wants to twist during vibration, just let it, else the rod can break.

5. Every second hole should be vibrated. Before one test, the vibration holes marked by dot on the wooden plates are vibrated and before the next test, the non-marked holes are vibrated and so on for the following tests. This is done just to ensure a more uniform compaction of the soil by not vibrating in the same holes every time.

6. After vibration is finished, the hose from the bottom of the sad box opened for the drain in the sewerage “Out”. The water level is decreased to about 1 cm of water above the sand surface. It is important that the draining of the water is done in low speed. The valve can be open to 50% of its capacity.

7. Unclamp the aluminium frame and take out from the sand box. Remove the rubber ring.
8. Level the sand surface using an aluminium beam.

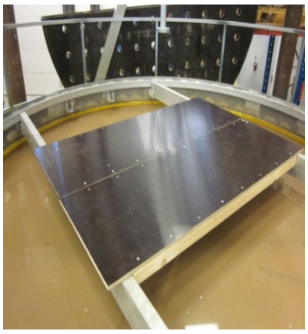


5. CPT Testing in the Sandbox

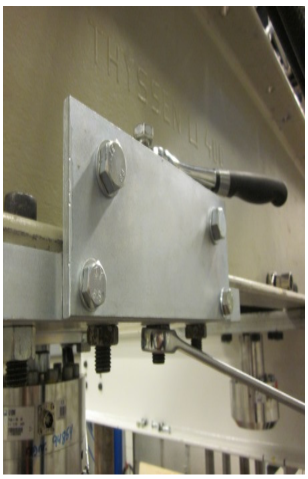
5.1 Preparing the equipment

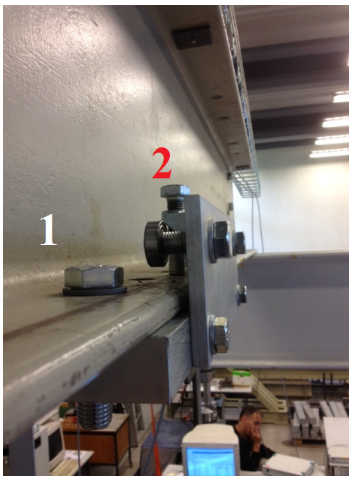
1. Repeat steps 4.2.2-4.2.4.
2. Make sure that the holding beam is fixed in the centre of the rig (Chapter 3, Figure 2 (6)). If not, then move it to the centre, rise up the wheels by the use of the screw, and tighten the large bolt.

3. Prepper working space.

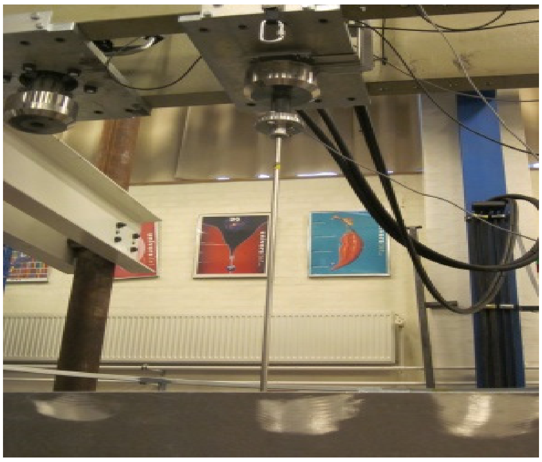


4. Position in the installation/CPT hydraulic cylinder (Chapter 3, Figure 2 (7)) in the point CPT1. Tighten bolts “2” on both sides of the beam.

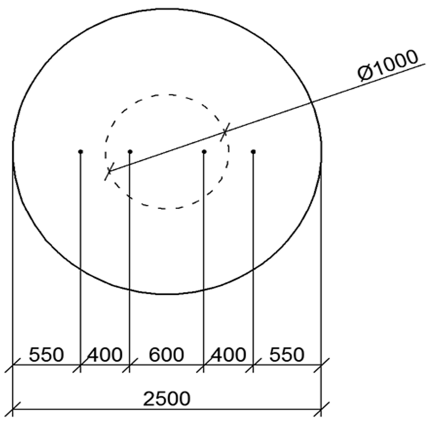




5. The CPT is mounted on the installation/CPT hydraulic cylinder. Displacement transducer is permanently attached to the hydraulic cylinder. It has to be used with care and cannot be left unattended, because it is sensitive. Ensure the verticality of the CPT rod.



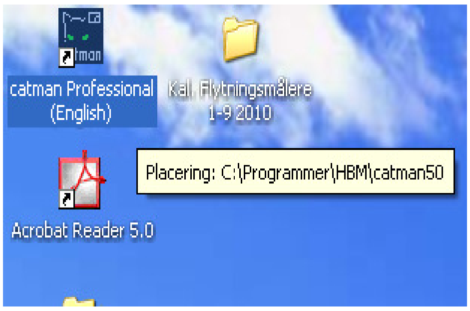
6. Four CPTs are carried out. The locations of CPTs are marked by black dots, and the distances are written in mm. For a bucket of 500 mm skirt length, CPT is sampled to 600 mm depth.



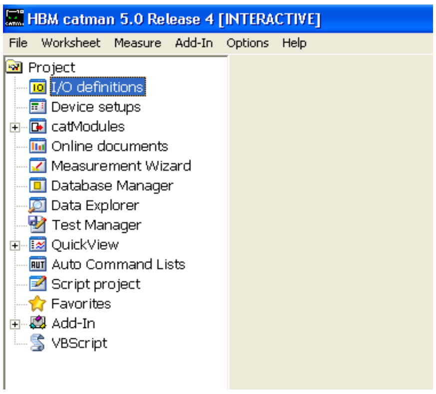
5.2 CPT data sampling in Catman

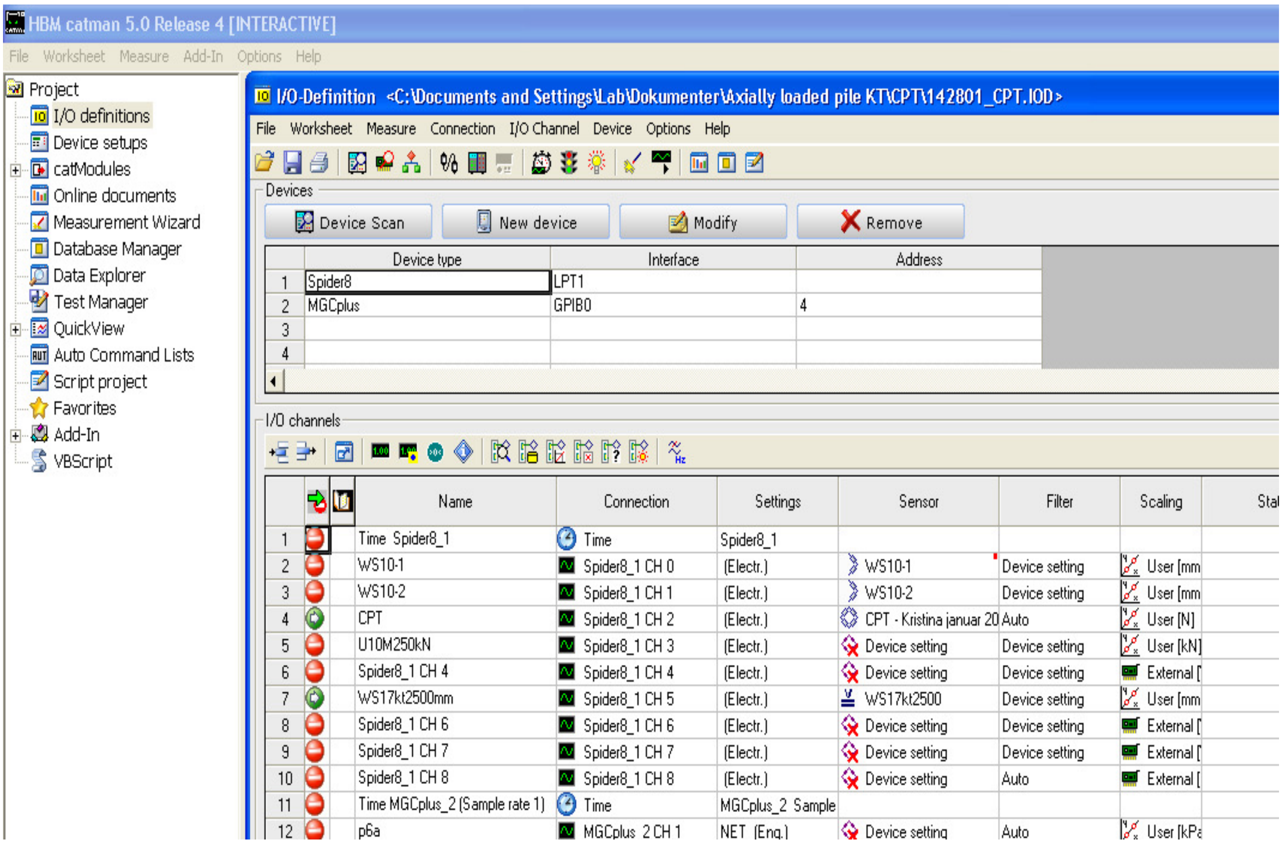
For more detailed description of this procedure, please, use Thomassen (2015b).

1. The CPT and displacement transducers are connected to the Spider8 system:
2. Use the program *Catman Professional* on the computer to record the information during the test.

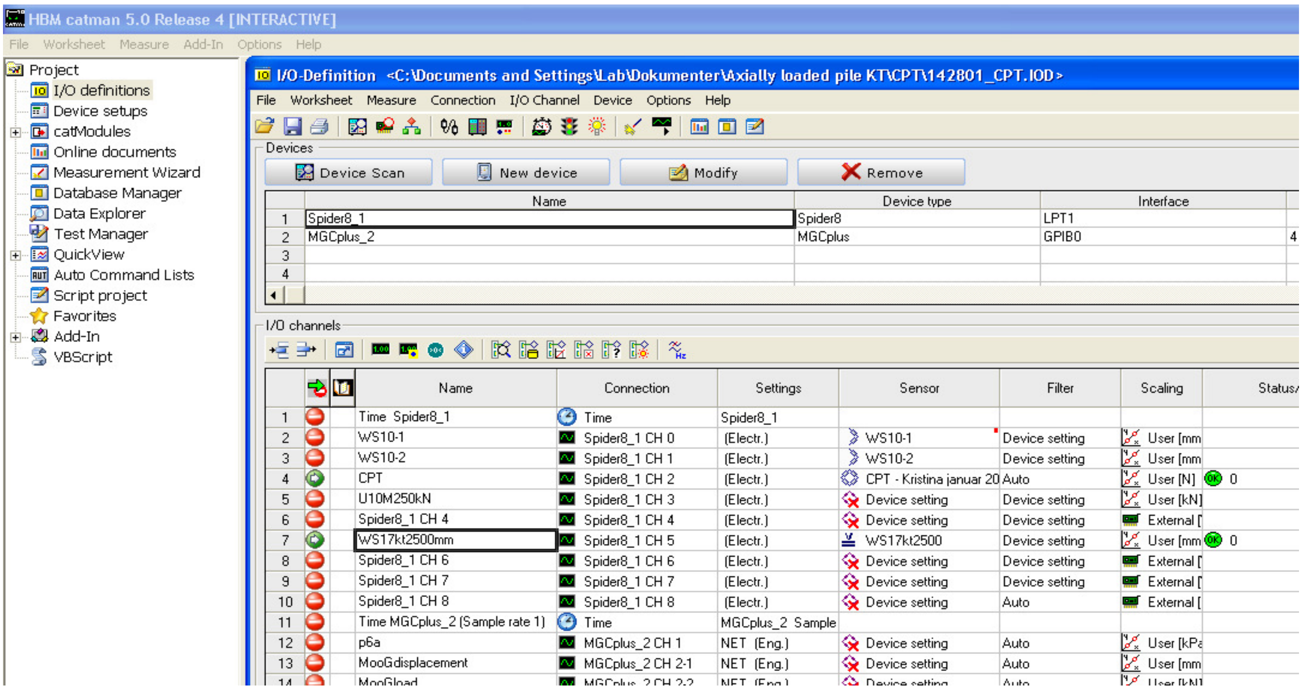


3. Start *Catman* and open *I/O definitions* to load the required file (e.g., C:\Documents and settings\Lab\Dokumenter\bucket\CPT.IOD).

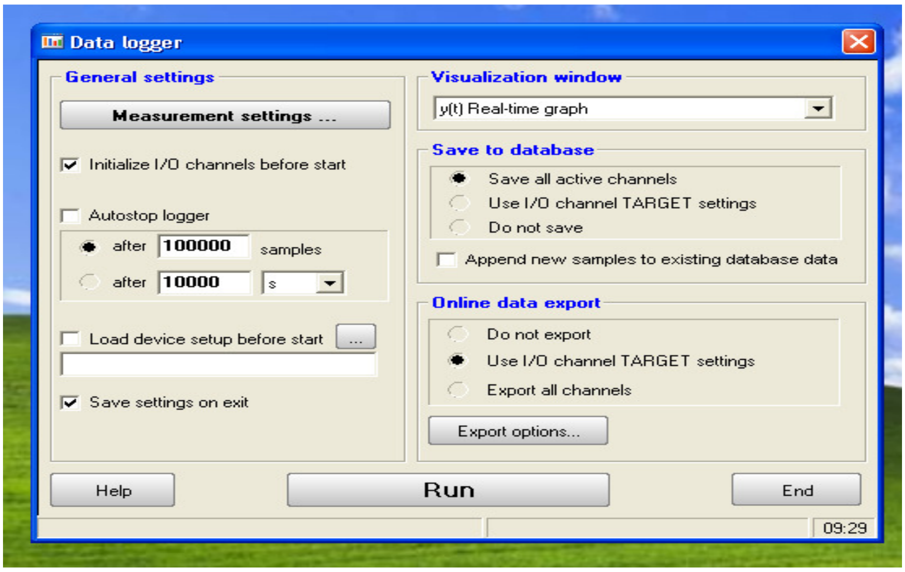




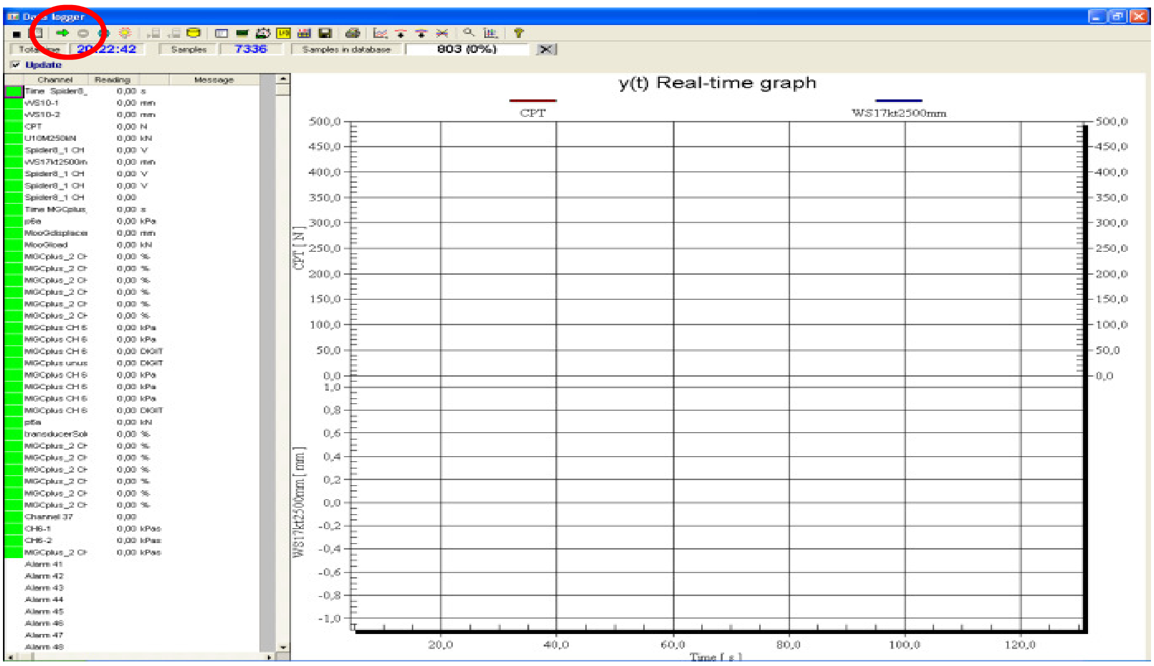
4. If the file is open, information about a lot of sensors will be displayed, but only two of them will be active - *CPT Load* and *CPT Displacement.*
5. Device settings->Set 12 mV/V for the CPT cone.
6. CPT device is positioned so that the cone tip is situated on the sand surface and the measurements are set to zero. This is done by marking the transducer in *Catman* and right clicking on it, *Set to zero* is chosen.



7. To start recording, data logger should be opened (CatModules->Measuring->Data logger). The settings for it should be standard and should not be changed.

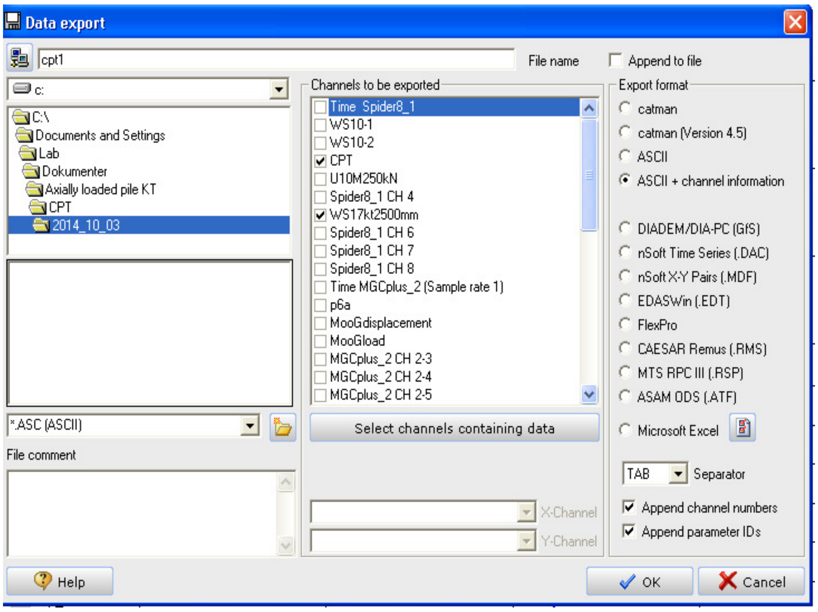


8. A graph will be shown on the screen. Desired parameters can be chosen to be displayed on the graph in time.
9. Click on the green arrow to start measuring.



10. Now the CPT testing can start. The movement of the CPT is controlled by a yellow controller. The test is conducting with a penetration speed of 5mm/s, which can be checked on the control panel mounted on the wall. When desired depth is reached (600 mm for the small bucket), the CPT is stopped together with the data recording and the device is slowly taken out of the sand.

11. The data from the two relevant channels in *Catman* is saved as ASCII+ channel information file, which can be used further for determination of the soil parameters as. The same procedure is repeated for the other three CPT locations.



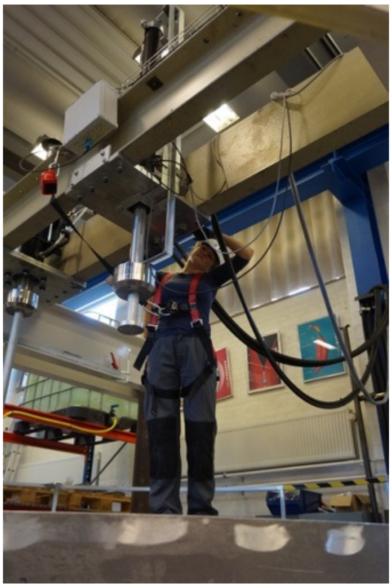
If satisfactory results are achieved, the test procedure can continue to Chapter 6. If required relative density is too low, the sand can be vibrated more until good results are shown in the CPT data. On the other hand, if the soil is too dense, the gradient can be started for some minutes to loosen up the soil.

6. Installation

6.1 Preparing the equipment

1. Place back the aluminium frame with four beams and the two vibration panels as earlier explained (section 4.3).
2. The bucket model must be cleaned well from previous use. Push out the dry sand (if there is some) from the bucket pipes by the compressed air and afterwards clean it with towel. However, you cannot blow compressed air to the pore pressure transducers. Always keep the cables and plugs protected from sand or water.

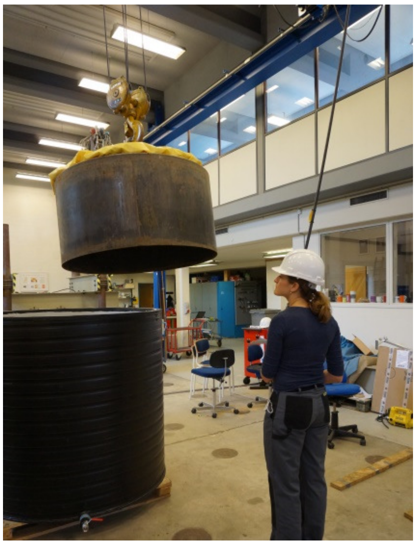
3. Position in the installation/CPT hydraulic cylinder in the centre. For tests with membrane go to section 6.2 and for tests without membrane to section 6.3.



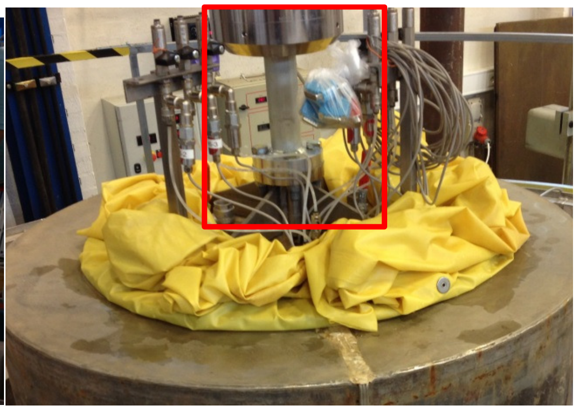
6.2 Installation of a bucket WITH the membrane

1. Fix the membrane to the bucket. Until December 2014 a thin yellow membrane was used, after that it was changed to a thicker blue membrane, because it proved to be more durable.

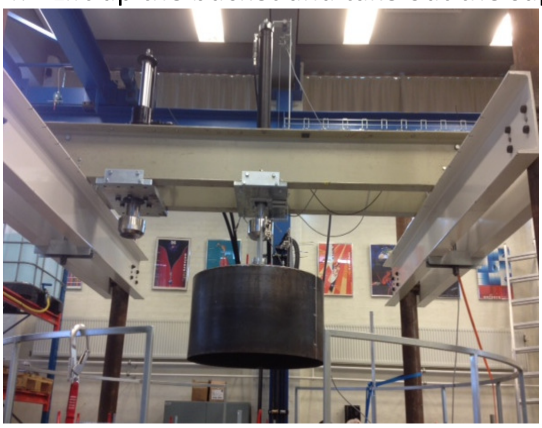
2. Afterward, the bucket is raised with crane and submerged in a water tank. Using a pump connected to the pore water pressured sensors, air is removed from the pipes of the bucket. Opening and closing the valves can help in the procedure. In the end the valves are closed. The pour water pressure sensors must be protected to avoid shocks onto them.



3. Take out the bucket from the water tank and situate it under the pressure cell on the sand box (use crane and manual pushing). Fix the bucket to the installation cylinder by an intermediate part. Tighten up the four bolts.



4. Lift up the bucket and take out the supporting panels and the two middle beams.



5. Place the bucket just above the surface of the sand. Tare the displacement and load measurement.

6. Install the bucket, speed 0.2 mm/s. The speed is selected in frequency transformation box. Installation force is measured by a load cell (MGCplus), remember to connect the load and displacement sensors. Use Catman for data recording. Leave the two big valves open! The 500 m length skirt must reach 70 kN preload.

7. When the bucket is installed, dissemble the installation cylinder and move it aside. Leave the red bucket valves open.
8. Place at least one small timber panel on the ring (to use a support when standing) and fix the actuator, but do not connect it to the bucket yet.
9. Remove the beams and the rubber ring, clean carefully the groove and place in it a thin layer of rubber.

10. Spread evenly the layer of filter and the membrane.

11. Push into the groove a circle-section rubber ring (ø9 mm).

12. Carefully position the smaller aluminium ring on the circumference of the sand box.

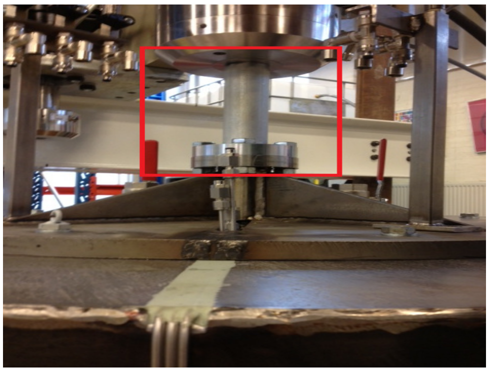
13. Clamp the frame to the sand box edge with four clamps, one to each side of the setup (1-4). Check that all clamps fit tightly.

6.3 Installation of a bucket WITHOUT the membrane

1. The bucket is raised with crane and submerged in a water tank. Using a pump connected to the pore water pressured sensors, air is removed from the pipes of the bucket. Opening and closing

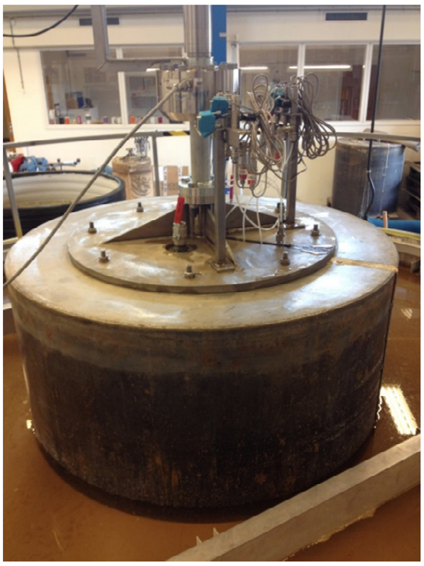
the valves can help in the procedure. In the end the valves are closed. The pour water pressure sensors must be protected to avoid shocks onto them. See figures in step 6.2.2.

2. Take out the bucket from the water tank and situate it under the pressure cell on the sand box (use crane and manual pushing). Fix the bucket to the installation cylinder by an intermediate part. Tighten up the four bolts.



3. Lift up the bucket and take out the supporting panels and the two middle beams. See figure in step 6.2.4.

4. Place the bucket just above the surface of the sand. Tare the displacement and load measurement.



5. Install the bucket, speed 0.2 mm/s. The speed is selected in frequency transformation box. Installation force is measured by a load cell (MGCplus), remember to connect the load and displacement sensors. Use Catman for data recording. Leave the two big valves open! The 500 m length skirt must reach 70 kN preload. See figure in step 6.2.6.

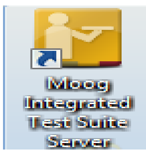
6. When the bucket is installed, dissemble the installation cylinder and move it aside. Leave the red bucket valves open.

7. Place at least one small timber panel on the support structure (to use a support when standing) and fix the actuator, but do not connect it to the bucket yet.

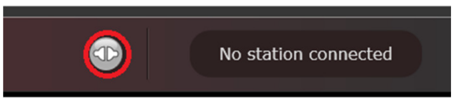
7. Connecting Actuator

It is highly recommended to read MOOG manual before working with the system.

1. Start MOOG computer.
2. Yellow MOOG icon on a desktop, when it says started at the bottom then the red icon of MOOG.



3. Connect the controller – connect station (indicated by green light)
4. If it turns to red color then restart the hardware by popping up button Clear Interlock.

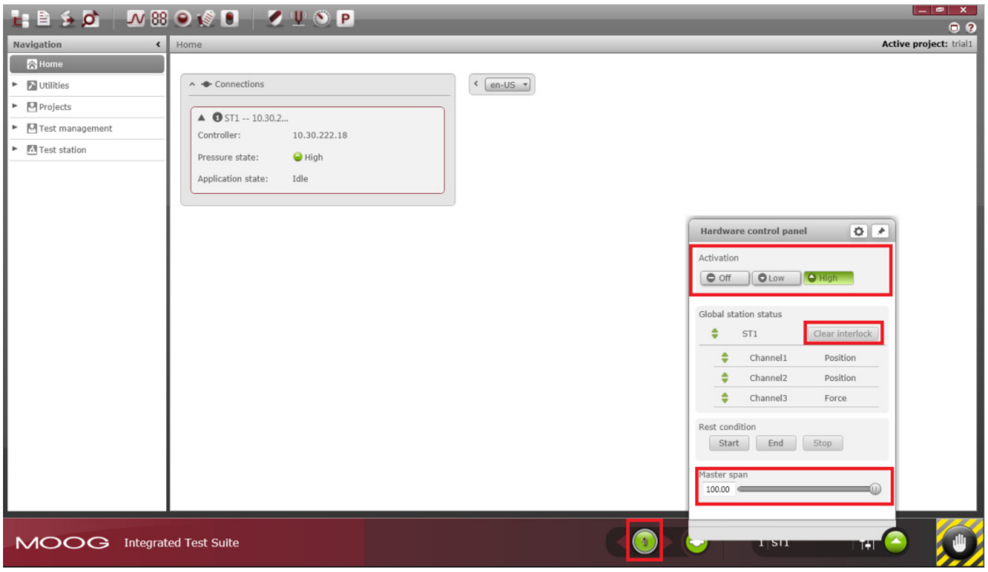


5. Turn on the hydraulic system (green button on the wall - start).
6. The hydraulic pump should be started by pressing the button in the station bar and choosing *low*. Modes of the Hardware, can be changed from Off -> Low -> High. Click on High to increase the pressure in the pipes. Be aware that the cylinder might move due to the change of the pressure and therefore do not have any body parts under the cell. Strange sounds from the pressure cylinder are common when turning on the system.

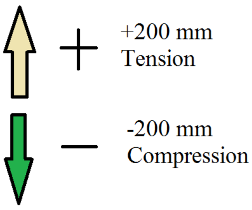
Low – prone to arbitrary and slowly change position of the piston

High – keeps full operative pressure, can abruptly move (dangerous)

NEVER switched on if anyone working directly under the actuator or with it.

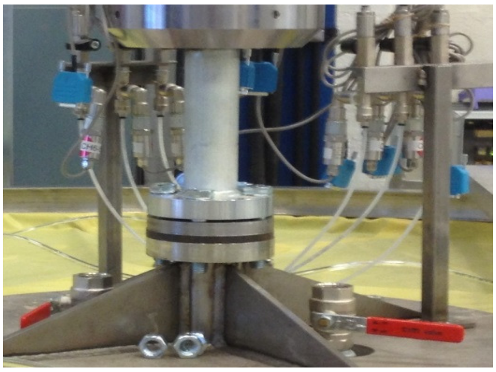


7. Press "Setpoint and span". The graph shows the position of the hydraulic piston at the given time. "Setpoint" is the position of the hydraulic cylinder; 200 mm means that the cylinder is in its uppermost position. The span of the cylinder is from 200 mm to -200 mm. By changing the number in "Setpoint",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

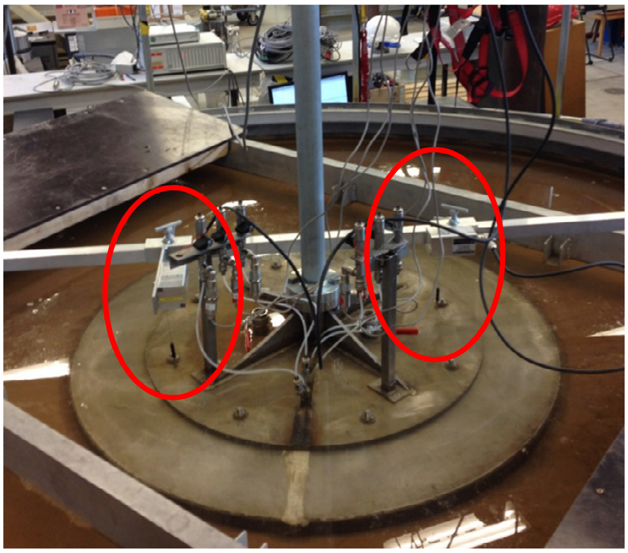


8. Test the actuators cyclic response before connecting to the bucket.

9. Carefully connect the actuator to the bucket. Bucket can be lightly preloaded, e.g. 5 kN, when fixing the bolts. Unload bucket to 0 kN. Close the read valves. From now on the MOOG equipment works all the time.



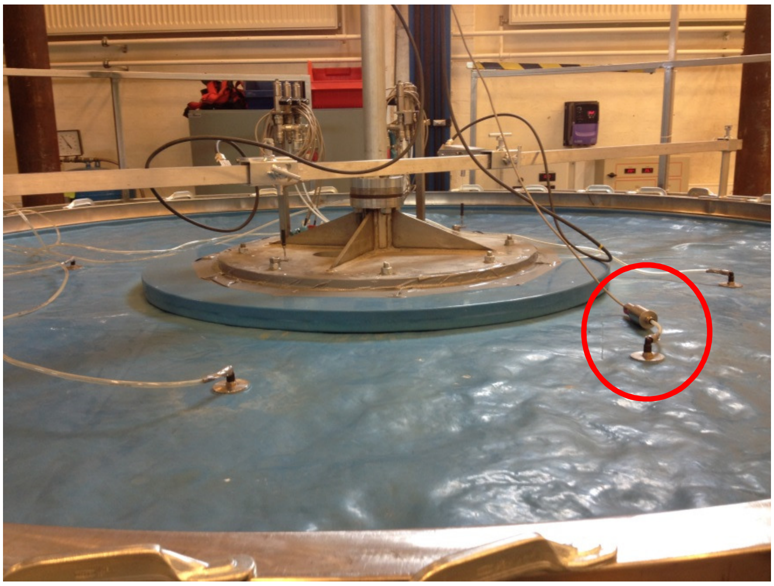
10. Mount two external displacement transducers (e.g. HBM WS10, 125 mm). Connect them to the transducer box.



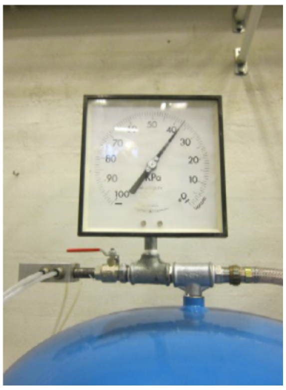
11. Connect pore pressure transducers to the transducer box. Make sure that displacement, load and all pressure transducers are connected.
12. Proceed to chapter 9 if the test is without the membrane.

8. Pressure Application on the Membrane

1. Connect a pressure transducer to the membrane.



2. Connect four suction piles to the membrane.
3. Zero pressure measurements in Catman (you may also zero the rest of the transducers). See also chapter 10 for more information about Catman or read HBM Catman Professional manual.
4. Turn on the vacuum pump and regulate until the wanted suction level is reached, then open the valve for suction from the sand box.



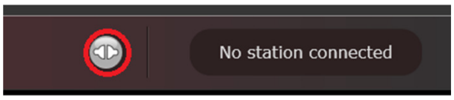
5. When required suction is established, mark down the measurement of the load cell in MOOG. For example, at 70 kPa suction it can be about 23 kN. This load is impacting load cell due to the membrane suction. It must be considered when analysing data and planning the loading program.

9. Setting the Loading Program and sampling in MOOG

The detailed description is made for long term loading, such as cyclic loading, but the principle is similar to short term loading. It is highly recommended to read the MOOG manual before using the equipment.

9.1 Setting the loading program and sampling in MOOG

1. Yellow MOOG icon on a desktop, when it says started at the bottom then the red icon of MOOG.
2. Create new project and fill out project name + description, then Save
3. Connect the controller – connect station (indicated by green light)
4. If it turns to red colour then restart the hardware by popping up button Clear Interlock.

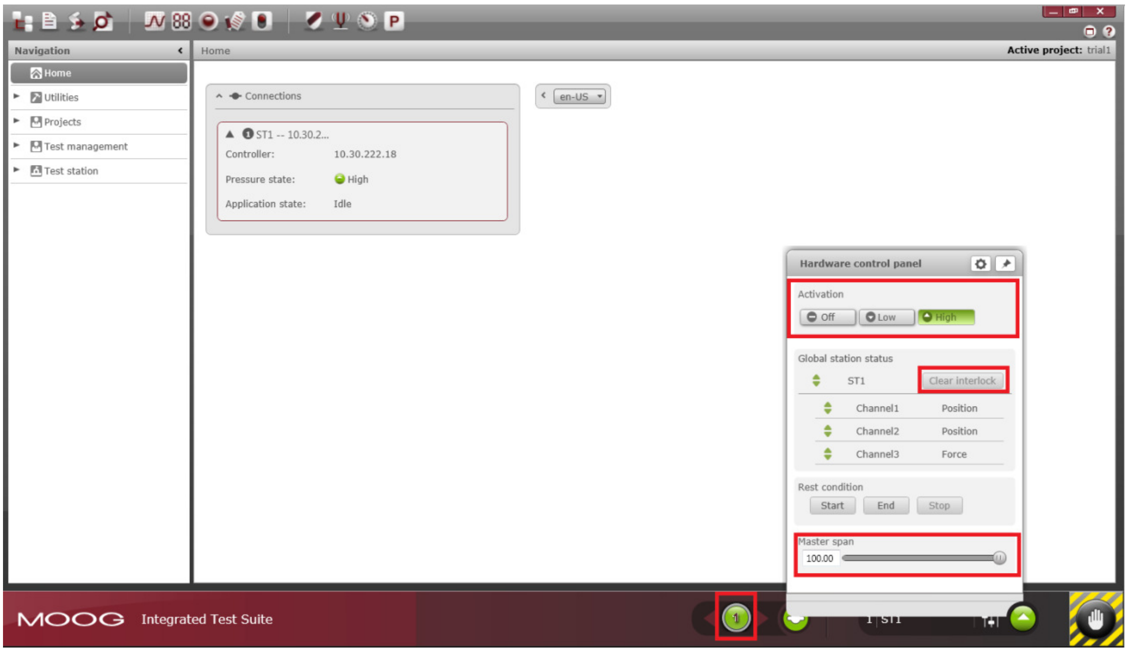


5. Turn on the hydraulic system (green button on the wall - start).
6. The hydraulic pump should be started by pressing the button in the station bar and choosing *low*. Modes of the Hardware, can be changed from Off -> Low -> High. Click on High to increase the pressure in the pipes. Be aware that the cylinder might move due to the change of the pressure and therefore do not have any body parts under the cell. Strange sounds from the pressure cylinder are common when turning on the system.

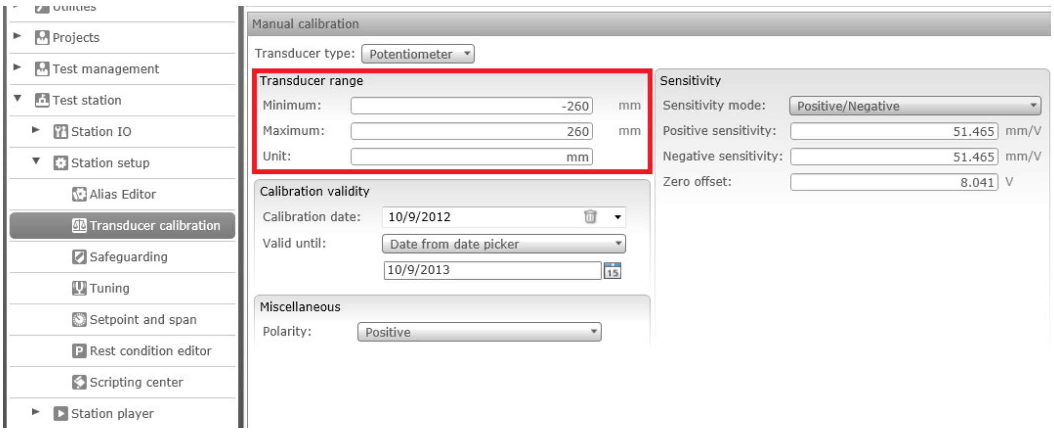
Low – prone to arbitrary and slowly change position of the piston

High – keeps full operative pressure, can abruptly move (dangerous)

NEVER switch on if anyone is working directly under the actuator or with it.

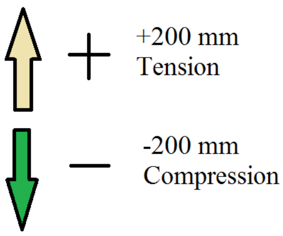


7. Master span represents ratio between inserted load and applied load
8. Settings:
    - First of all the coordinate system needs to be reviewed. (Ranges might be different from device to device).



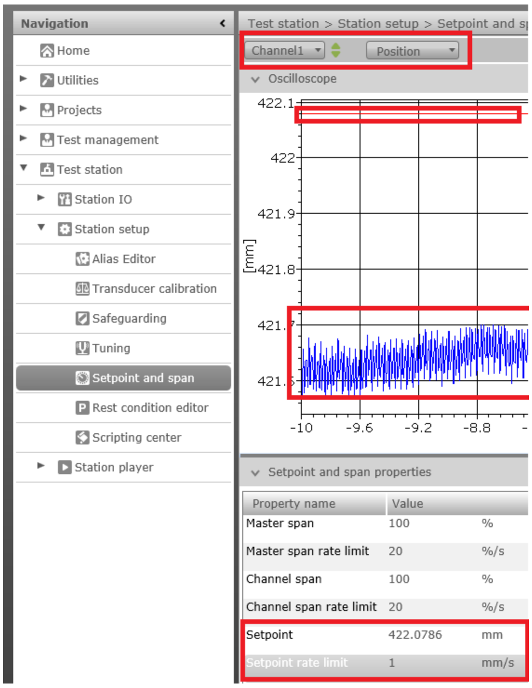
<u>Test station</u> -> <u>Station setup</u> -> <u>Transducer calibration</u>

- Important to choose the correct <u>Channel</u> and its attribute. Needs to be taken into account that total minimum and maximum cannot be reached exactly, for example limit -200 mm goes max to -199.5 mm.



- Setpoint and span, the graph represents the position of the piston at the given time. Setpoint is the position of the hydraulic cylinder in coordinate system, can be adjusted by choosing a proper channel and changing a position/force.

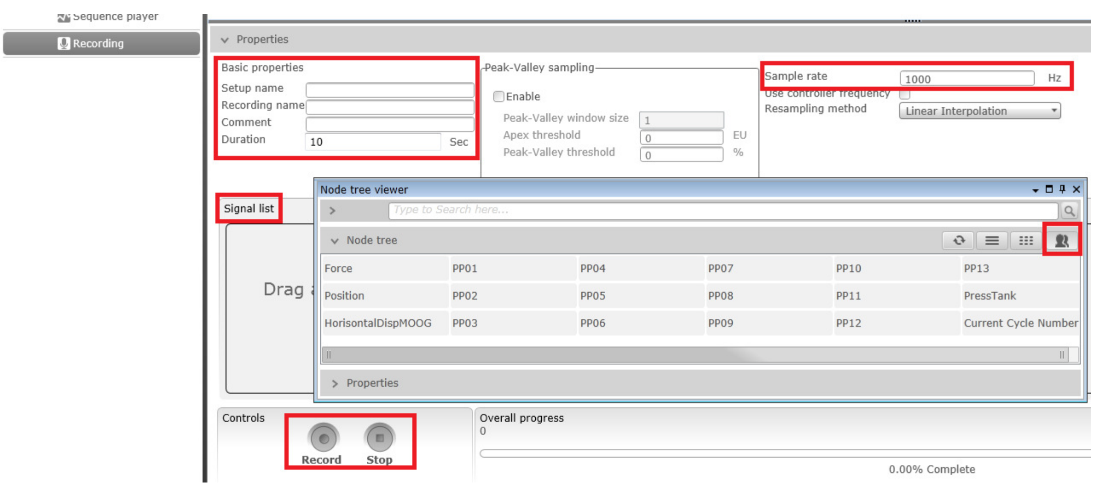
*To change the position be aware that MOOG reacts immediately after value is changed and confirmed by <u>ENTER</u> (only moves when hardware is set on <u>High</u>), therefore first of all the rate limit (mm/s) needs to be changed. The piston will move with the chosen velocity. It is safe to start with 0.1 mm/s.



- Red curve represents anticipated behaviour
- Blue curve is real measured behaviour.
- An extra oscilloscope and digital meter can be added for better coordination. (Drag and drop from the tree at the left)

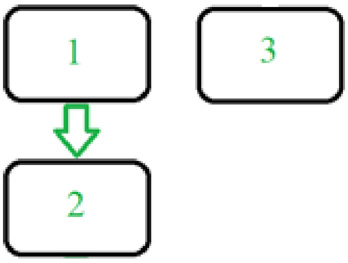
9. Recording of the entire procedure(including moving with the piston):

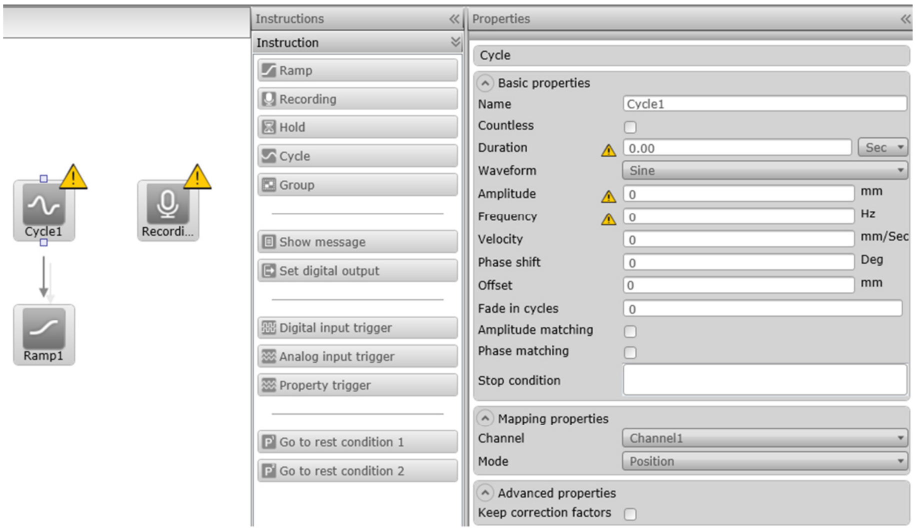
- General information needs to be filled out including <u>duration</u> in seconds and <u>sample rate</u> in Hz. To signal list, the channels which should recorded can be dragged.



9.2 Option 1 (works):

1. Create a new loading program: Test management -> Test browser ->Create and insert a name then click next.
2. Set the Setpoint to the starting point of the cyclic loading. Velocity in *kN/s*, End value in *+X kN*. (Pull)
3. Load Mode Cyclic: Number of cycles *Y*, Wave form *sin*, Amplitude *+X kN*, Frequency *Z Hz*, Offset *0 kN*.
4. Load Mode Ramp: Velocity in *mm/s*, Transition type RAMP, End value in *+X mm*. (Pull)
5. Record: Sequence duration, Force and Displacement.





6. Save -> Load -> (Start Catman sampling) ->Play.
7. The arrow between (1) and (2) and no arrow to (3) are VERY important.
8. Safeguarding - option where we can set safety boundary conditions for an experiment does not work perfectly, because the displacement transducer is mounted on the actuator and not on the bucket and there are different defections in the system. Therefore, it cannot be relied on it 100%.
9. When the experiment is accomplished recorded, data can be saved: Utilities -> Data browser, export in format CSV.

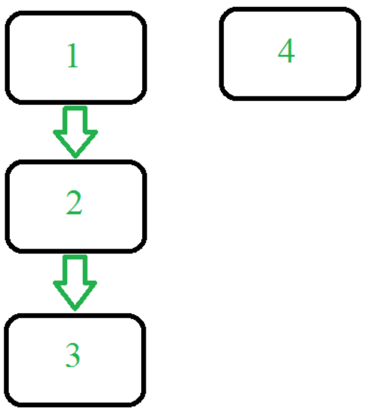
9.3 Option 2 (works, manual):

1. Recording only external in this case

2. Set the Setpoint to the starting point of the cyclic loading. Velocity in *kN/s*, End value in *+X kN*. (Pull
3. Set cycles: Number of cycles *Y*, Wave form *sin*, Amplitude +*X kN*, Frequency *Z Hz*.
4. Set the Setpoint to the final pull-out: Velocity in *mm/s*, Transition type RAMP, End value in *+X mm*. (Pull)

9.4 Option 3 (does not work always):

1. Create a new project – loading program.
2. Load Mode Ramp: Duration in *s*, Transition type RAMP, End value in *+X kN*. (Pull)
3. Load Mode Cyclic: Number of cycles *Y*, Wave form *sin*, Amplitude +*X kN*, Frequency *Z Hz*, Offset *+X kN*.
4. Load Mode Ramp: Duration in *s*, Transition type RAMP, End value in *-2 kN*. Easier to unscrew bolts.
5. Record: Sequence duration, Force and Displacement.



9.5 Testing Static Axially Loaded Bucket with MOOG

1. Set the safeguarding limits for loads and displacements.

2. Set extra recording if wanted.

3. Create a new project – loading program.

4. Load Mode Ramp: Velocity in mm/s, Transition type RAMP, End value in +X mm. (Pull)

5. Load Mode Ramp: Duration in s, Transition type RAMP, End value in -2 kN.

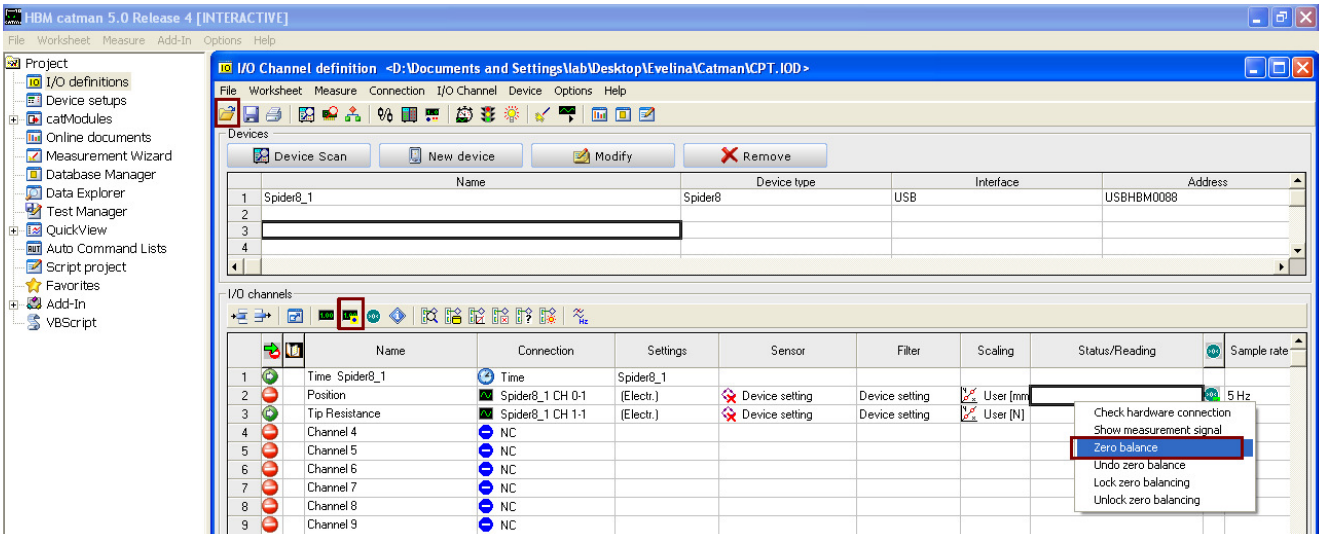
6. Record: Sequence duration, Force and Displacement.

7. Save -> Load -> Play

10. Data Sampling in Catman (long-term)

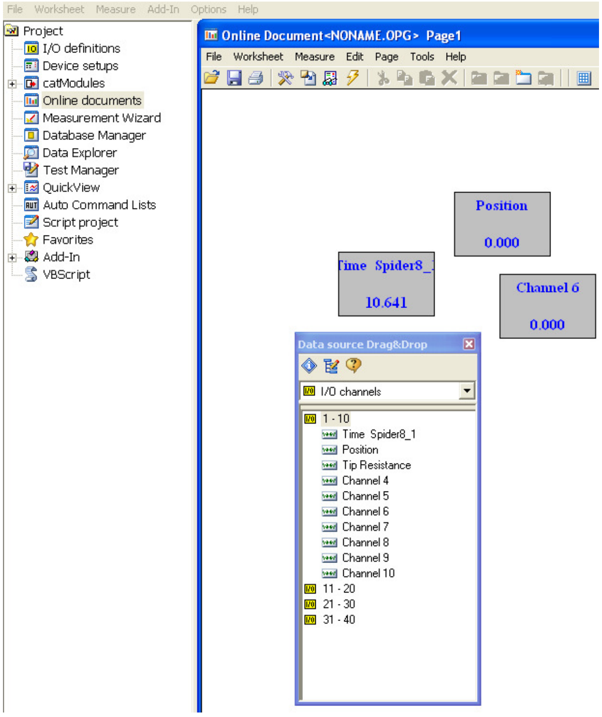
Make sure that all the connections are correctly placed and the Data Acquisition system with all the connections is switched on. During this testing program two Data Acquisition systems are used: during installation and CPT testing – Spider8, and during loading sequence – MGCplus. The two systems CANNOT work together at the same time, because it brings up numerous errors in the data sampling. The following information is written for a Spider8 box, but it is the same for MGCplus.

1. I/O definitions – input/output
2. Set up the measuring channels (can be loaded template file). To review the connections click on continuous readings of channels to see actual values.

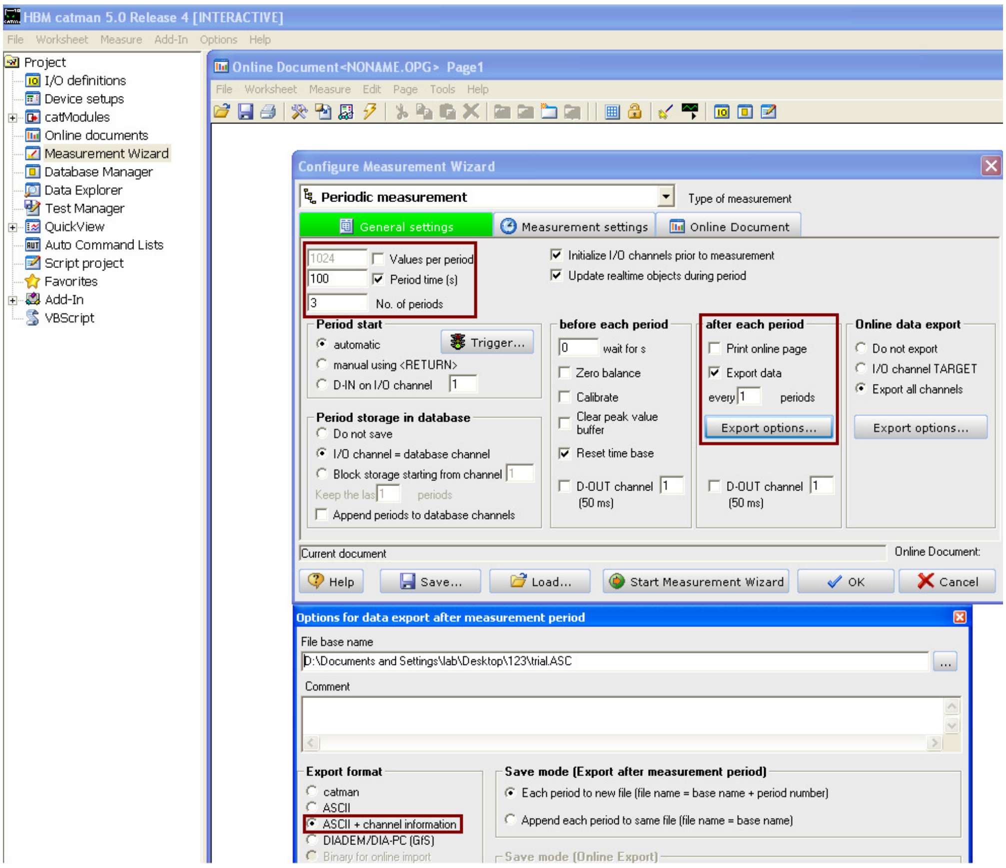


3. Before every measurement, it is a good idea to <u>Zero balance</u> the status of all channels, for easier reading afterwards.

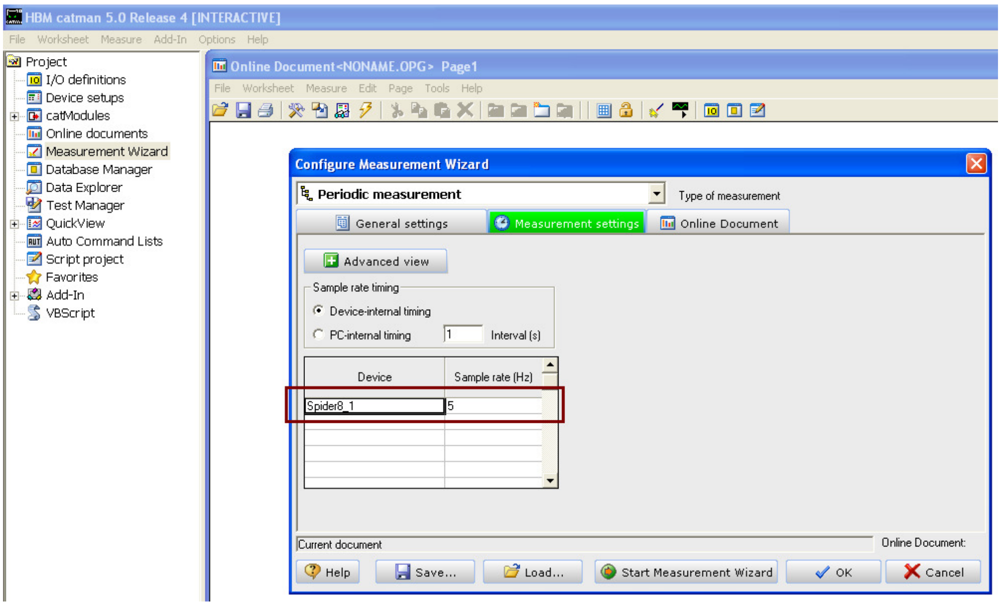
4. Prepper the Online document:
   - Drag and drop wanted channels in to the space, or load template OPG file.



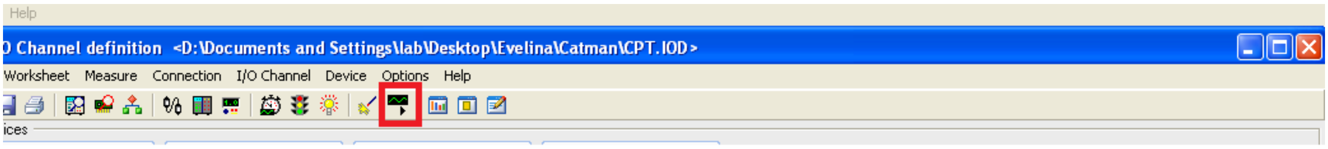
   - Prepper the Measurement Wizard – settings of the recording.
   - Important to fill out <u>Period time</u> and <u>number of periods</u>.



- Mark export data and set output format on ASCII+channel information.
- In Measurement settings, sample rate in Hz can be adjusted (min 2Hz for cyclic loading).



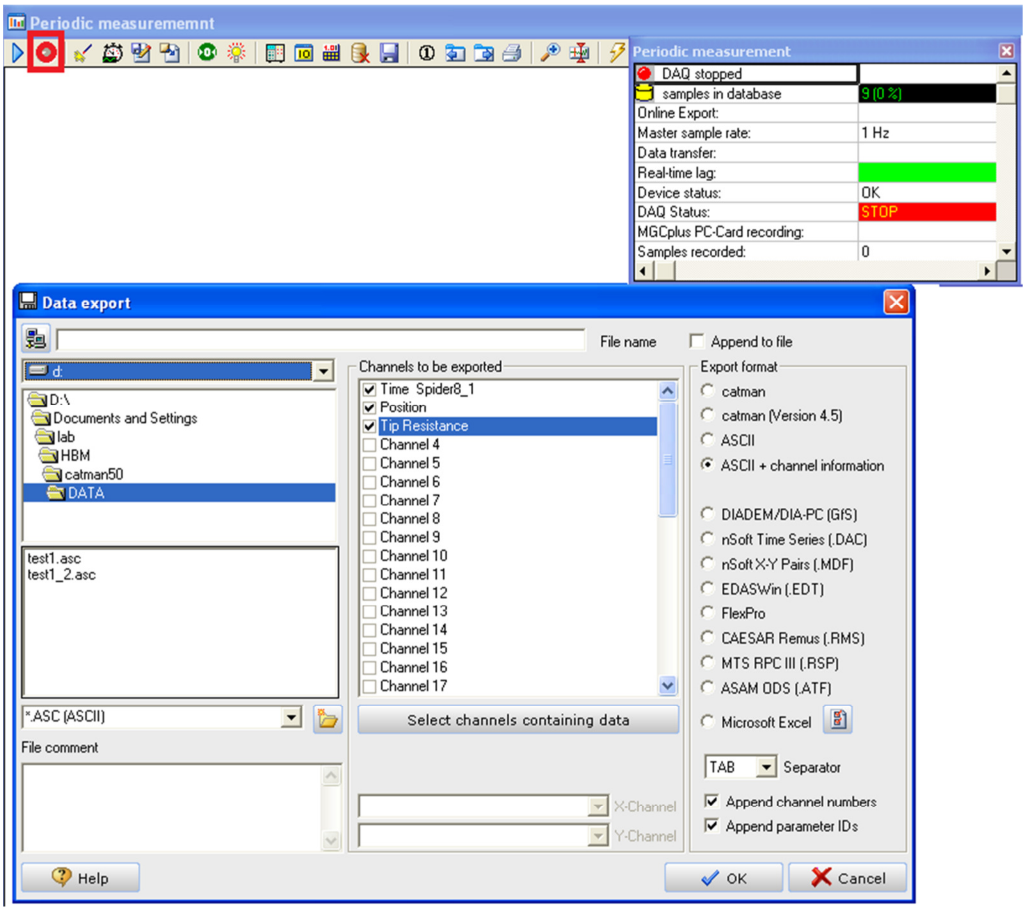
- When everything is set up, start recording by clicking on the following icon and then clock start at the top of the newly opened window.



- If everything goes fine the recorded output files will be saved automatically.

10.1 Stopping the data sampling and saving data in Catman manually

1. In need of abrupt interruption press the red button-stop at the top.
2. Note that interrupted file needs to be saved manually (files before interruption are saved automatically).



11. Switching off the MOOG System after the Test

1. Make sure all the data is saved.
2. Turn off the hardware in MOOG, step by step, from High -> Low -> Off, then Red button on the wall (on the hydraulic station).
3. If something goes wrong the emergency stop button can be pressed. The data can be saved manually in Catman.

12. References

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Vaitkunaite, E., Nielsen, B.N. and Ibsen, L.B. "Bucket Foundation Model Testing under Tensile Axial Loading." *(Submitted)*, 2015.

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