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by

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Table of Contents

1. Objective

This technical report describes the set-up and the test procedures for installation and uninstallation of medium-scale model of bucket foundation that can be performed in the geotechnical part of laboratory in Aalborg University. The installation of bucket foundation can be tested with the use of suction under the bucket lid or by applying additional force through the hydraulic piston, forcing the bucket to penetrate into the soil. Tests for uninstallation are performed also with the use of water pressure, as a reverse process to the suction installation. Both installation and uninstallation tests are adjusted for additional weight that simulates different self-weight of foundation. The medium-scale model of bucket foundation corresponds to 1:10 of a prototype model. Additionally, the procedure for soil preparation and the data acquisition methods are provided. The sand box (Large Yellow Box) and loading frame used for those tests have been already used for axially static and cyclic loading of piles (Thomassen, 2015a) and for axially static and cyclic loading of bucket foundation (Vaitkunaite et al., 2015).

2. Safety rules and safety equipment

A general rules on safety in Laboratory of Aalborg University are described by Vaitkunaite (2015).

- ✓ Always read specifications and manuals related to work and chosen set-up/ equipment.
- ✓ The tools that are used should always be cleaned and returned to their original place.

For the "Large Yellow Box" the safety equipment that must be used is as following:

- ✓ Safety shoes - use always in the Laboratory
- ✓ Helmet - use always when working with the testing rig and crane; allowed not to wear helmet while seated on the computer only
- ✓ Safety belt – use when working on the rig in standing position
- ✓ Earplugs – use when vibrating
- ✓ Vibration gloves – use when vibrating
- ✓ Knee protection – recommended to use while vibrating
- ✓ Gloves – recommended to use during work around the rig

Remember! 1 hour of vibration must be followed by 1 hour of other type of work.

3. Test set-up

The set-up consists of a large diameter steel box with sand. The internal diameter of sand box is of 2.5m and the height of box is of 1.52m. During all tests sand is saturated, therefore a special drainage system is required at the bottom of sand container. First, perforated pipes are equally placed. Pipes are covered in 0.3m of thickness gravel layer, and 1.2m of thickness sand layer. Large permeability of gravel prevents from piping problems and provides a uniform water pressure. Additionally, the geotextile cloth is used between gravel and sand.

Water is inserted into or removed from the sand container through the system of valves situated outside, near the bottom (drainage system). Additionally, an ascension pipe is connected to this system, so the upward gradient can be measured and maintained at the same level during loosening process. The water is received from a big water container situated near the rig.

Model of bucket foundation is installed with the use of hydraulic piston adjusted to a loading frame. The load can be measured through loading cell. During installation/uninstallation, the displacement is measured by the displacement transducer mounted on the connection piece between the load cell and the bucket model, which moves constantly with the foundation.

The vacuum pump used for suction installation is situated near the rig and can be connected to valves through hoses.

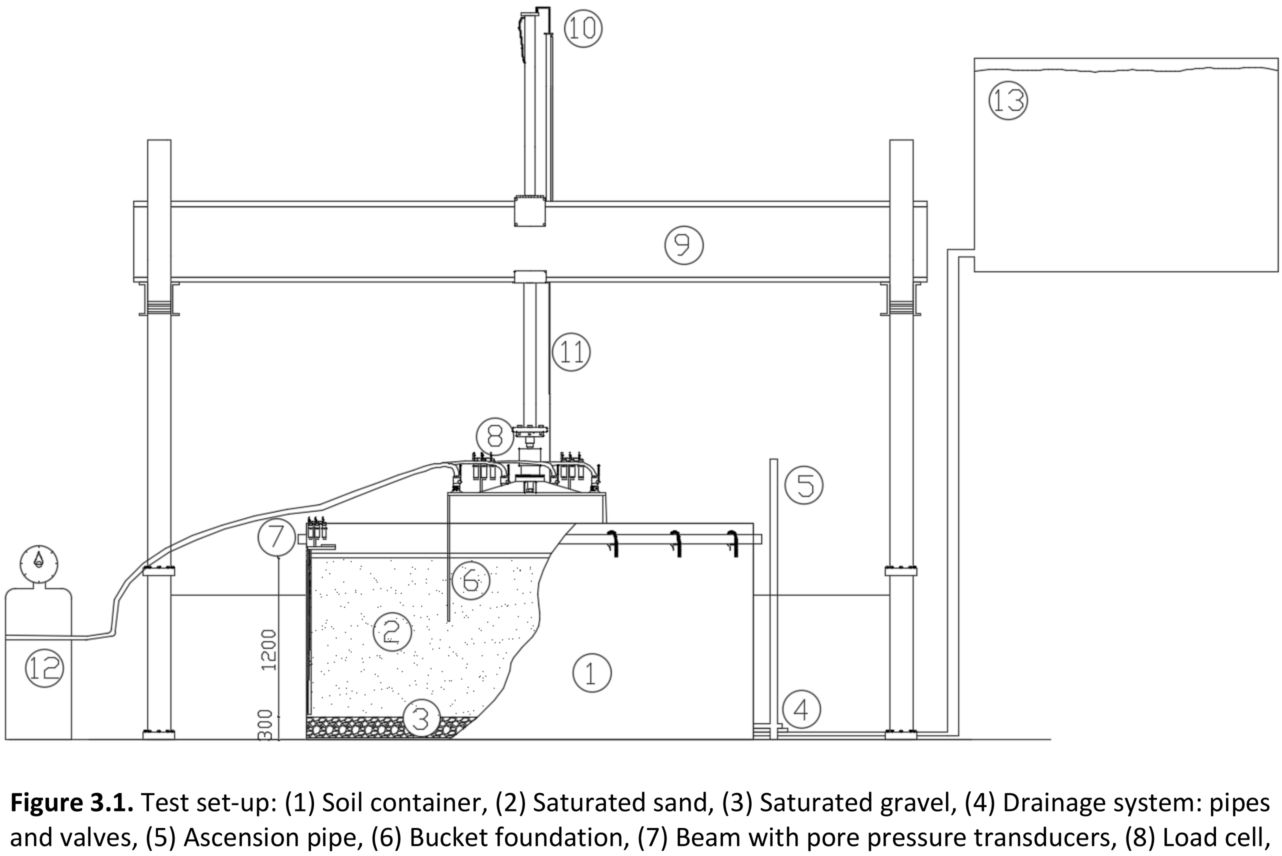


Figure 3.1. Test set-up: (1) Soil container, (2) Saturated sand, (3) Saturated gravel, (4) Drainage system: pipes and valves, (5) Ascension pipe, (6) Bucket foundation, (7) Beam with pore pressure transducers, (8) Load cell, (9) Loading frame, (10) Hydraulic piston, (11) Displacement transducer, (12) Vacuum pump, (13) Water tank; (dimensions in mm)

3.1. Properties of soil

Soil material used for tests is a Baskarp Sand No.15. This type of soil was previously tested at Aalborg University accounting for soil properties.

Table 3.1. Properties of Baskarp Sand No. 15 (Borup and Hedegaard,1995)

Specific grain density, $\boldsymbol{d_s}$	2.64	[g/cm^3]
Maximum void ratio, $\boldsymbol{e_{max}}$	0.854	[-]
Minimum void ratio, $\boldsymbol{e_{min}}$	0.549	[-]
50%-quantile, $\boldsymbol{d_{50}}$	0.14	[mm]
Uniformity coefficient, $\boldsymbol{C_u = d_{60}/\ d_{10}}$	1.78	[-]

3.2. Model of bucket foundation

Figure 3.2 shows a medium-scale model of bucket foundation equipped with all measurement systems. The bucket has a diameter of 1000mm and skirt length of 500mm. The thickness of the lid is 20mm.

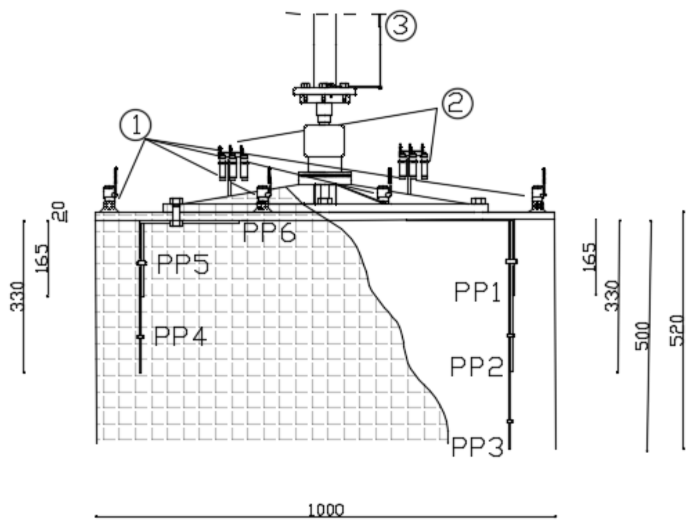


Figure 3.2. Model of bucket foundation: (1) Valves, (2) pressure transducers, (3) displacement transducer, (PP1 - PP6) positions for the pore pressure measurements (dimensions in mm)

Pore pressure transducers are attached to the foundation, at the top of bucket lid. Pore pressure is measured continuously in 6 positions (PP1-PP6 in Figure 3.2.). Pore pressure is measured in 1/3 and 2/3 of bucket skirt length and at the tip of bucket skirt at the end of open pipes. The signal is recorded in [mV/V]. The sensitivity of pressure transducers is often given by the producer, however, it is recommended to perform a calibration procedure at the beginning of test campaign, see Appendix C. The bucket lid is also equipped with 4 valves that are used for applying a suction pressure under the bucket lid during installation.

3.3. Specification of the test parts

An external displacement transducer is fixed to the loading frame with a clamp and the censor is fixed close to the center of bucket lid, by keeping it vertical, see Figure 3.1. (11). The transducer has a range of 1500mm.

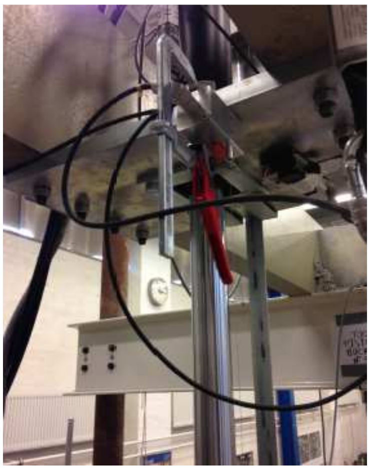


Figure 3.3. Displacement transducer clamped to the loading frame

The water can enter or leave the sand container through the drainage system at the bottom of sand container. Three valves are used to control the inflow and outflow, "In" and "Out", and to check the value of applied hydraulic gradient, "Gradient". The valves are open when they are parallel to the pipes.

Figure 3.4. Valves controlling the incoming and the outgoing water supply of the yellow sandbox

A beam with pore pressure transducer is installed prior to each test to measure excess pore pressure at the boundary condition. Measuring system works the same as for pressure transducers at the bucket foundation.

There are six transducers attached, however, there is a need to use only three of them. Dimensions are given below.

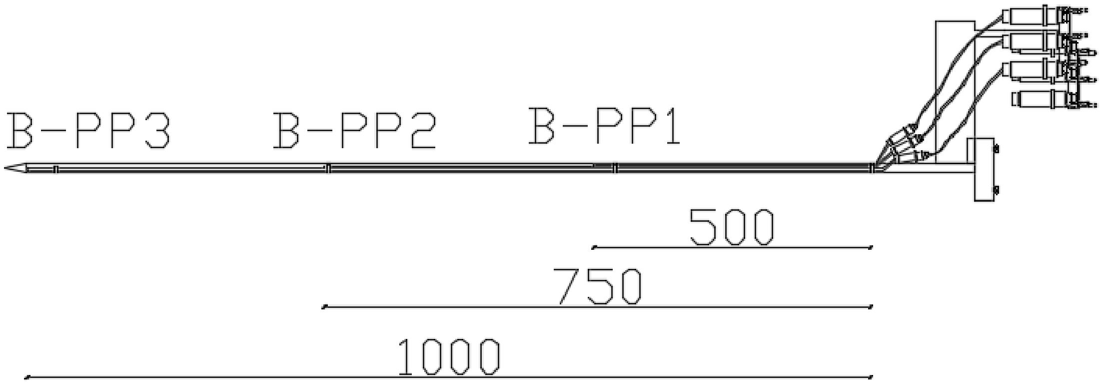


Figure 3.5. Model of beam with pore pressure transducers

Vacuum pump is used to apply the pressure difference on the bucket lid required for suction installation. Vacuum pump is equipped with a manometer. The system is connected to the compressed air system of the laboratory.

Figure 3.6. A vacuum pump with manometer

Hydraulic piston is used for CPT tests and also for installation. There are two different head for the piston, one which is a displacement controlled and the other one, which is a force controlled. Former is used for CPT and the latter is used during installation. The piston works due to the hydraulic motor and the settings are adjusted on two switchboards, both situated on the wall, behind the test rig. A yellow controller is used for starting/ending the piston work and also could be used to adjust the speed manually.

On the control switchboard it can be chosen between “deformation speed” and “load speed” by the black knob. The desired speed can also be set on the same switchboard on the left side. The black knob is used for adjusting the speed which is displayed on the panel below.

(a) (b) (c) (d)

Figure 3.7. Control for hydraulic piston: (a) hydraulic motor, (b) control switchboard, (c) setting switchboard and (d) controller.

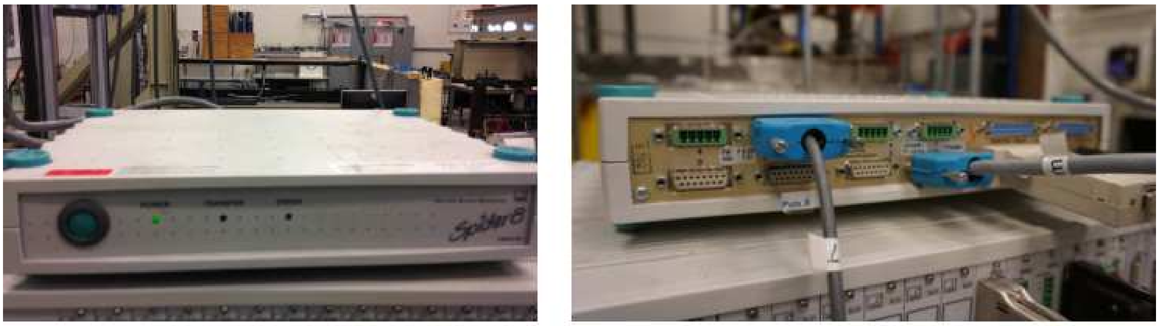
On the control switchboard the deformation/ loading speed must be adjusted for control gain. Only then the hydraulic motor will work correctly. To switch between the gains, the middle bottom in the upper row. Then adjust the values using up- and down-arrows.

Table 3.2. Values for setting switchboard

PI Control Gain	**deformation speed**	**load speed**
P-41	0,8	3,0
P-42	2,5	1,0

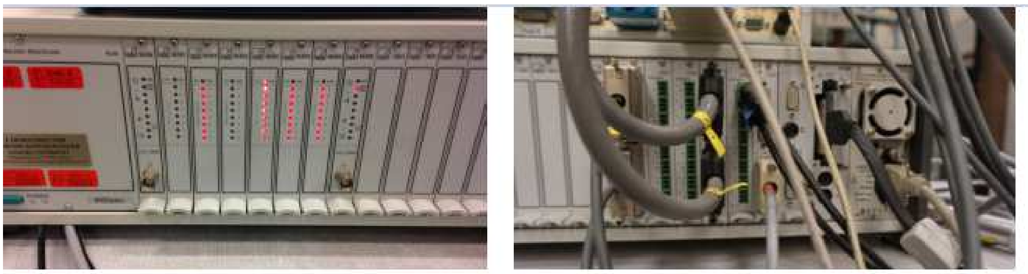
For the displacement control loading, the motor should not work. The knob on the blue motor should be screwed to the left until it cannot continue. For the ‘load speed’ it should be turned to the left for the entire rotation two times plus a bit more, until the line marked on it is reached.

Data from CPT device and Load cell are acquired in HBM Spider8. Data from pore pressure transducers, air pressure transducer and displacement transducers are acquired in HBM MGC Plus.



(a) (b)

Figure 3.8. Data acquisition devices Spider8: (a) front of the device, (b) connection in the back of the device



(a) (b)

Figure 3.9. Data acquisition device MGC Plus: (a) front of the device, (b) connections in the back of the device

Connection of cables is easier if the connection boxes are used. Then boxes are connected directly to the data acquisition devices. There is one box situated in the center of the loading frame (for cone resistance and pressure transducers from the bucket foundation), and the other box is clamped to the loading frame at the edge, just above the place of beam installation (for pore pressure transducers from the beam).

If the cables are not connected to the acquisition devices, or signals are not recorder correctly, technicians from laboratory can be asked for help.

(a) (b) (c)

Figure 3.10. (a) Connection box for cone resistance and pore pressure transducers from the bucket foundation, (b) signed sockets on the connection box, and (c) Connection box for the pore pressure transducers from the beam

4. Soil preparation

Uniform compaction of sand is of a great importance. Soil conditions must additionally be similar between tests, so they can be fairly comparable. The soil preparation is indeed required, as after each test the soil is non-uniform, loosened in place of removed bucket foundation and densified around that area. The procedure is described by following steps. Such a procedure has already been used by other researchers and the results prove that a dense state condition is achieve, and soil condition between tests are comparable (Foglia et al., 2013, Vaitkunaite et al., 2014).

Pre-preparation:

After uninstallation the hole in sand in a place of bucket might be quiet big. Therefore the surface of soil can be leveled with the use of shovel, just to obtain an average equal level. This procedure is easier to perform while water level is reduced to be around 1cm above soil surface. If the level of surface was decreased too much as an effect of previous tests (compaction and suction applied), additional sand must be added.

Ensure that water tank is filled with water. If not, the valve for water access should be open and tank should be refilled. Remember to close the “in” valve to the sand container while refilling the water tank.

(a) (b)

Figure 5.1. (a) Water tank and (b) supply valve

The procedure of leveling the soil surface has been changed from the procedure previously used. However, if the procedure used in (Thomassen, 2015a, Vaitkunaite et al., 2015) is chosen, then an aluminum frame must be unclamped and removed for leveling. After, the edges of the yellow sand box must be cleaned from the sand with the use of air-piston and then wiped with paper. A rubber O-ring should also be washed and wiped with a towel before placing it evenly back on the edge of the yellow sand box. Finally the aluminum frame can be set and clamped. A correct position of the frame is possible by following the numbers indicated on both, the frame and the yellow sand box.

(a) (b) (c)

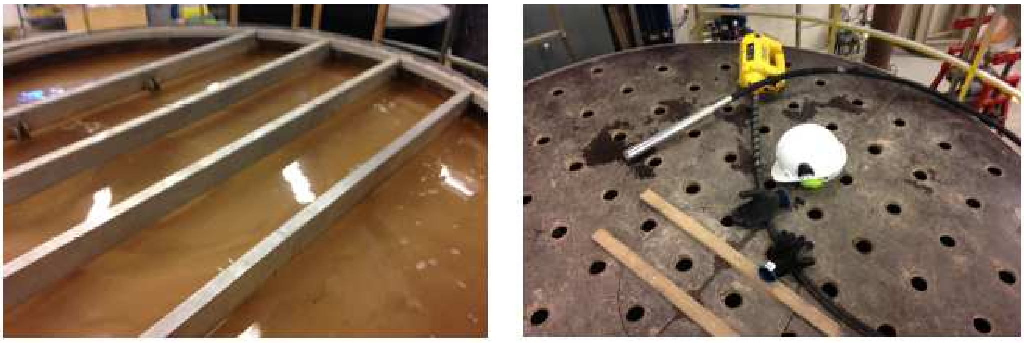
Figure 5.2. (a) Rubber O-ring placed correctly at the edge of yellow sand box, (b) Rings clamped around the container, (c) correct positioning of aluminum frame

Loosening of soil:

Soil is loosened with the use of upward hydraulic gradient. The water enters the yellow sand box through drainage system – the valve "In" is open. The valve "Gradient" should also be opened to control the value of hydraulic gradient on the ascension pipe. A hydraulic gradient, i, of 0.9 is applied (water level in the ascension pipe should reach the marked line) for around 10 min or, when water level was significantly reduced before, up till water level of 6-8 cm above soil surface is reached (it usually takes 30 minutes for reaching the desired level). Remember to close both valves when the loosening process is finished.

Vibration:

Four aluminum beams are placed on the aluminum ring according to the numbers placed on both, beams and the ring. Next, wooden plates with the holes are placed on top of the supporting beams. There are specific marks on the plates ensuring that they are placed exactly on top of the aluminum frame, without the holes being blocked by the beams.



(a) (b)

Figure 5.3. Working platform for vibration: (a) aluminum beams and (b) wooden plates

Remember about safety rules and equipment while vibrating (chapter 2). A rode vibrator is used to compact the sand. It is systematically pushed and pulled into the sand through the holes in wooden plate. To ensure a uniform compaction, the rod is inserted into every second hole, and the left holes on the way back. Firstly, the 20 holes in the middle, marked in square in Figure 5.4., are vibrated. After that all holes are vibrated, starting from one side, stripped holes, and then vibrating white holes on the way back (the holes in the middle square are vibrated twice). The vibration should be performed with the same, quite small speed downward and upward. The rod should be forced a bit during way down. When the rod gives a feeling as it starts to twist, it should be allowed. Otherwise, the rod might break.

After the end of the vibration the valve 'Out' should be opened to maximum 50% of its capacity to let the water flow slowly out of the container, until water level reaches approximately 1cm. The wooden plates and the aluminum beams are removed.

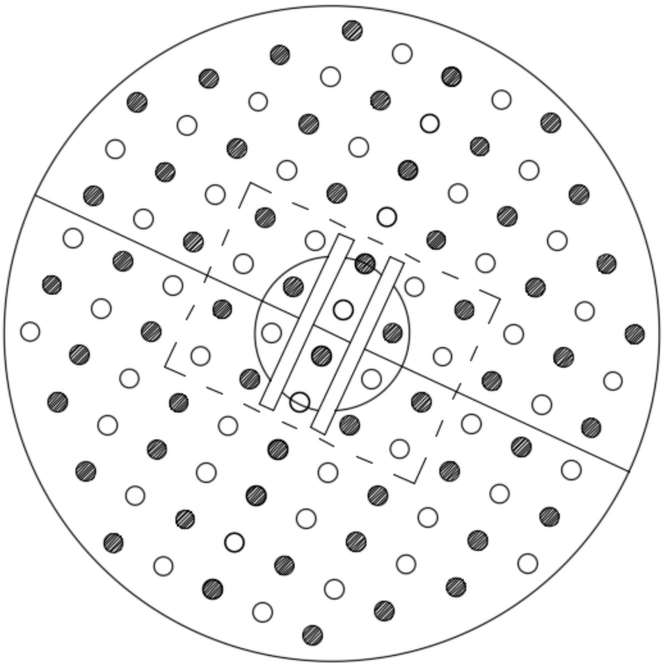


Figure 5.4. A plan for vibration; first middle dashed square, then whole plate, always every second hole

Leveling of the soil surface:

To improve the procedure, a new way was found for leveling the soil surface, so that the aluminum frame and the rubber O-ring do not need to be removed and fixed again between tests. A wooden plate is clamped on the aluminum beam (height of the wooden plate was chosen according to the distance to the soil surface. The beam is of the length that ensures it can be set on the aluminum frame of sand box. The wooden plate need to be of equal dimensions and clamped to the beam ensuring the equal level. With such a 'device' the soil surface is leveled by pushing the beam from both ends, performing a uniform rotation.

Figure 5.5. A beam with a wooden plate used for soil surface leveling

5. Cone penetration tests, CPT

Cone penetration tests, CPT-s, are performed before and after the installation of the bucket foundation in order to have a good overview of the soil resistance around the sandbox. CPT-s are conducted in 4 positions before the installation and in 8 positions after the bucket is fully installed.

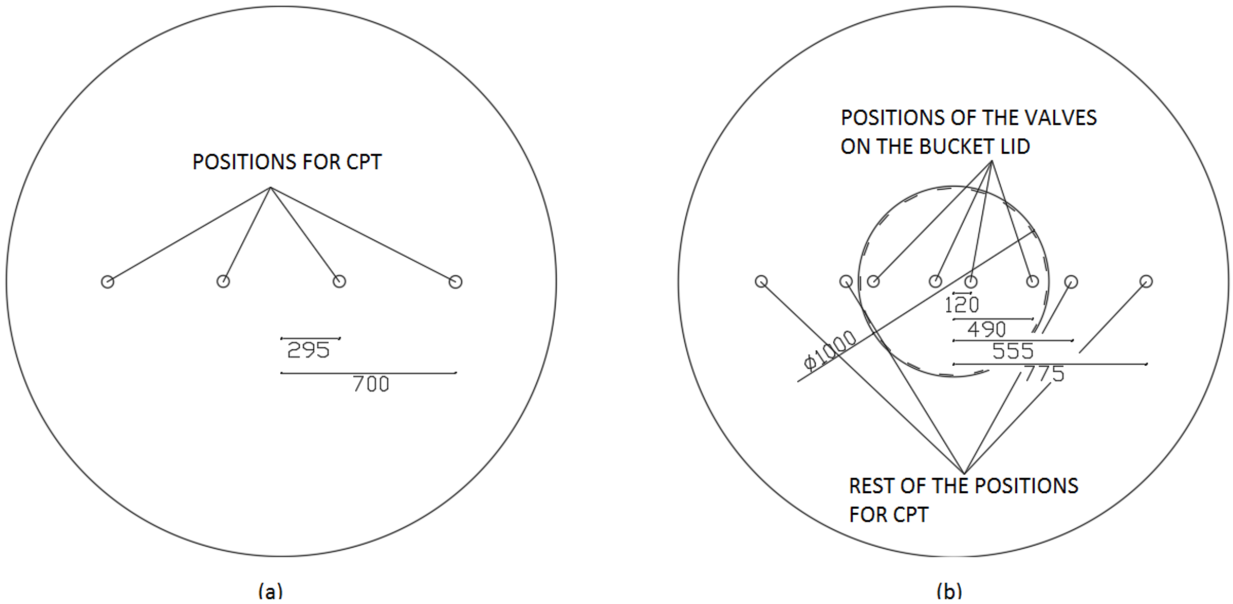


Figure 5.1. Positions for CPT-s (a) before and (b) after installation. CPT-s are also performed inside the valves of bucket foundation.

For a working space, two aluminum beams and two smaller wooden plates should be placed on the sand container. The loading frame should be placed in the center of the rig (normally it is always there, however it should be checked). A small cone penetration testing device is used. It is equipped with strain gauges inside the cone to measure the cone resistance. The diameter of a cone has 15 mm and a 30^{o} inclination. The CPT device must be calibrated from time to time. A calibration procedure is given in Appendix A.

The CPT device is mounted on a short aluminum beam, allowing it to be rotated. Two small bolts are used. Then all can be fixed to the hydraulic piston. The CPT device is connected to the transfer box fixed on the loading frame to the socket called 'Cone'. Before starting the test it must be ensured that CPT rode is in a vertical position.

(a) (b) (c)

Figure 5.2. Cone penetration tests: (a) Working platform, (b) A head extension for CPT device, (c) Mounted CPT device

Such a prepare cone penetration device should be moved to the desired position to perform a test. Positions are marked on the installation frame. To do that, the hydraulic piston should be untightened and moved along the loading frame. There are two bolts, on both sides of the frame that are used for this purpose.

(a) (b)

Figure 5.3. (a) A bolt that is tightened/untightened for moving the hydraulic piston, (b) positions for CPT-s marked on the loading frame

The hydraulic piston moves by using the yellow controller, up and down. . The CPT tests are performed with a speed of 5 mm/s (see section 3.3.). The records should start when the cone is situated just above the soil surface. Faster speed can be used to lower the CPT close to the soil surface (on yellow controller switched the black knob to maximum). There is a red mark on CPT rod indicating a 500mm depth. Stop the test when the value is reached using the red button on the yellow controller.

When data are saved, they must be checked. The results are satisfying if the sand is uniformly dense. The soil parameters can be derived according to Appendix B. To loose sand requires repeating of vibration procedure.

If the sand has a satisfying density in some places and is completely loose in others, the gradient should be applied again before vibrating.

6. Data acquisition from CPT

Signals from CPT tests are acquired through ‘Spider8’ and transferred to software called ‘Catman Proffesional’. Settings of the software are described in this section. The software is installed in the laboratory computer.

The program is opened and it can be scanned in order to find data acquisition device. Open ‘I/O Definitions’ and press on ‘Device scan’. For CPT records only ‘Spider8’ device is used. Then all setting should be adjusted. However, for the CPT tests an ‘-.IOD’ sheet has been prepared, which includes all required settings. The file name is ‘CPTsetup_thg.IOD’. It should be open in ‘I/O Definition’. If CPT-s are calibrated and calibration factors differ significantly, new settings are required, see Appendix A. Also if the settings are lost and new settings must be adjusted, the procedure is described by Thomassen (2015b).

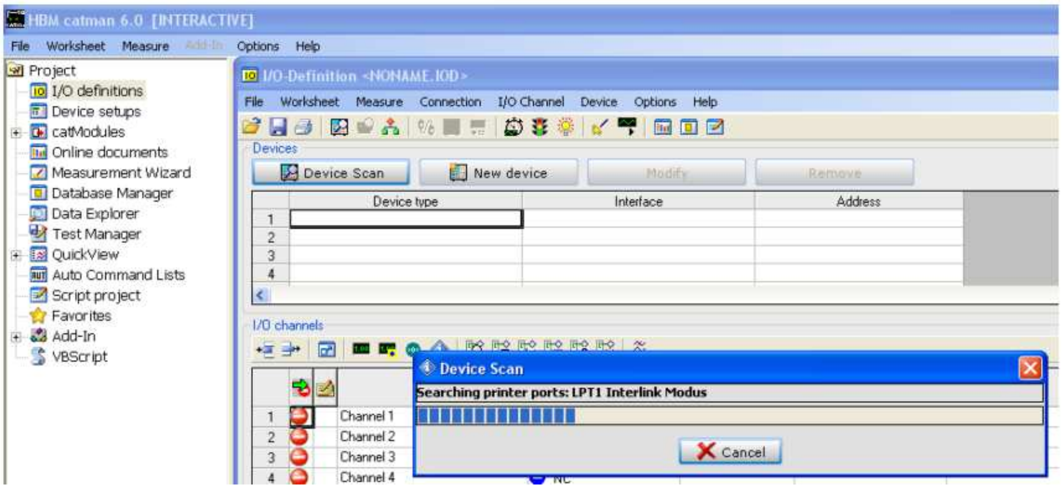


Figure 6.1. ‘Device scan’ in Catman for localize the data acquisition devices

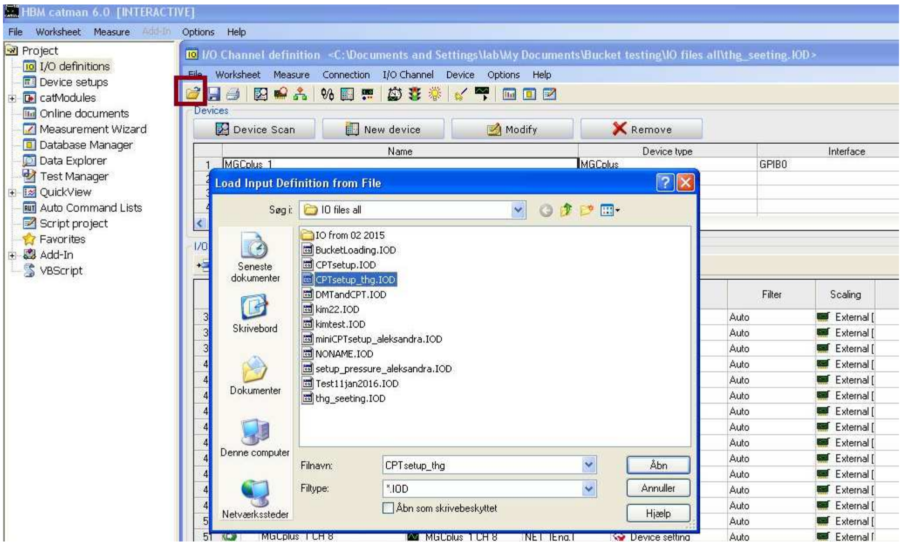


Figure 6.2. Procedure for uploading a file

When opening the file a lot of channels appear, where 'CPT cone', 'Installation displacement', 'Installation load' and 'Time' are active. Green arrows instead of red minus signs are displayed in the left most column in 'I/O Definitions'. The actual measurements can be observed by pressing the icon in 'I/O Definitions', see following figure. 'Continuous signal reading' can be used also to check if signals work correctly. For example, by touching gently transducers and noticing the small changes in signals.

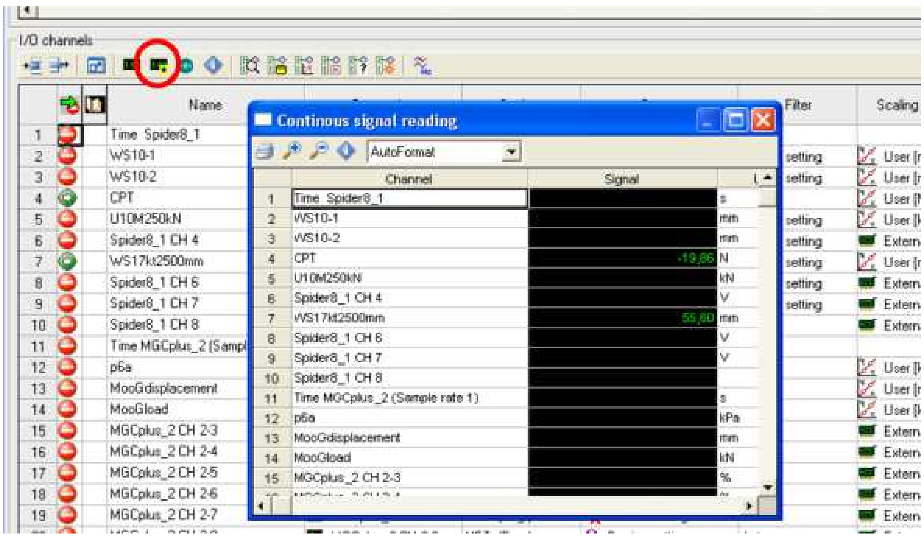


Figure 6.3. Continuous signal reading

Channels used for recording are 'CPT cone' and 'Installation displacement' and therefore, they should be zeroed before each test. A 'Zero' button is used, see following Figure. In the column 'Status/Reading' an 'OK' icon pops up with a value really close to zero. If value in this column differs still from zero, click 'Zero' button again.

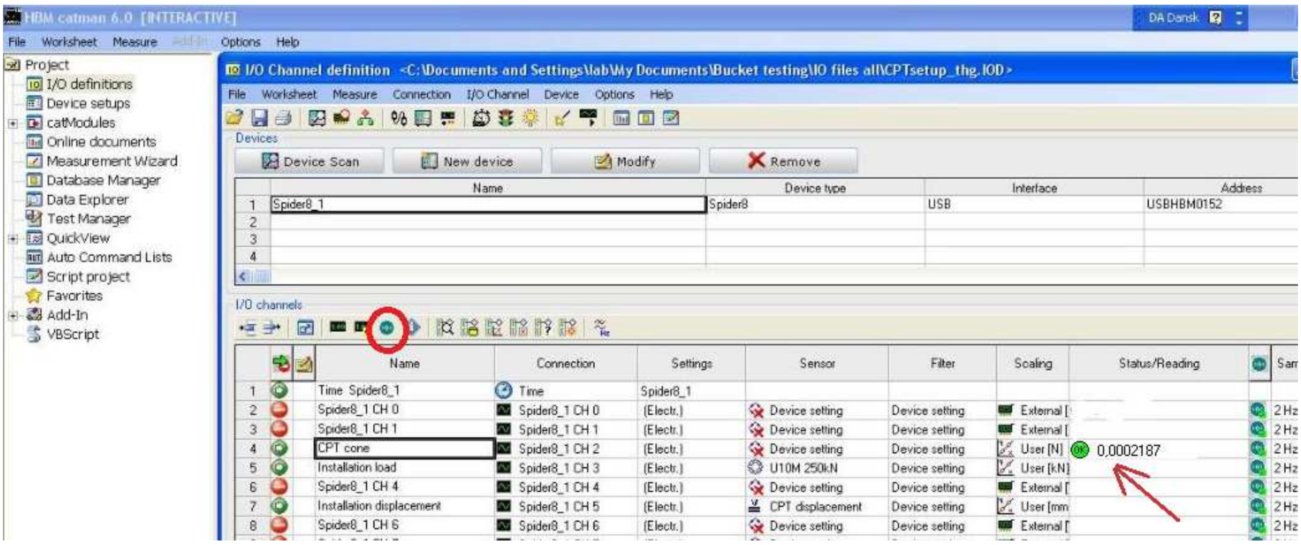


Figure 6.4. Active channels for CPT and zeroing procedure

The records are made in 'Data Logger'. From the 'Project' choose 'catModules', then 'Measuring' and finally 'Data Logger'. The window pops up. Any changes are needed. Press 'Run' button.

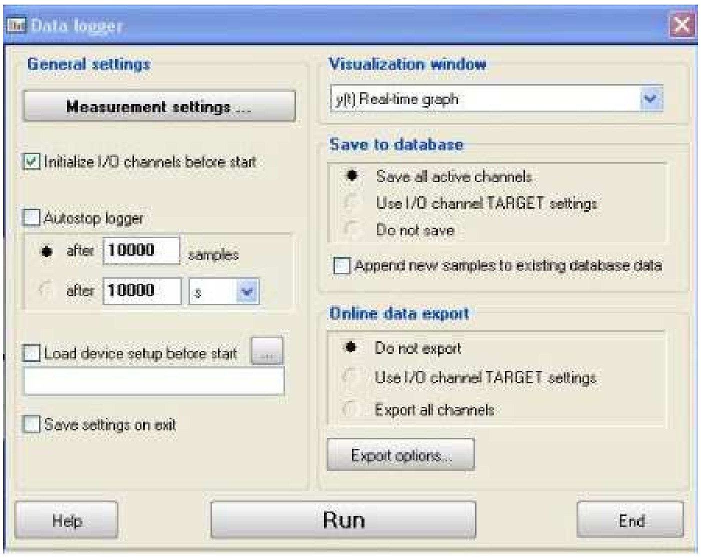


Figure 6.5. 'Data Logger'-setting window

A screen plot can be created in 'Data Logger' to observe penetration depth (displacement) and cone resistance at the same time.   Follow the steps:

- ✓ Right click on the plot
- ✓ 'Set up axes'
- ✓ 'Plots'
- ✓ Choose 'CPT cone' on the left axes
- ✓ Press 'Add new data plot
- ✓ Choose 'Installation displacement' on the right axis
- ✓ Press 'Add new data plot'
- ✓ Press 'Apply'.

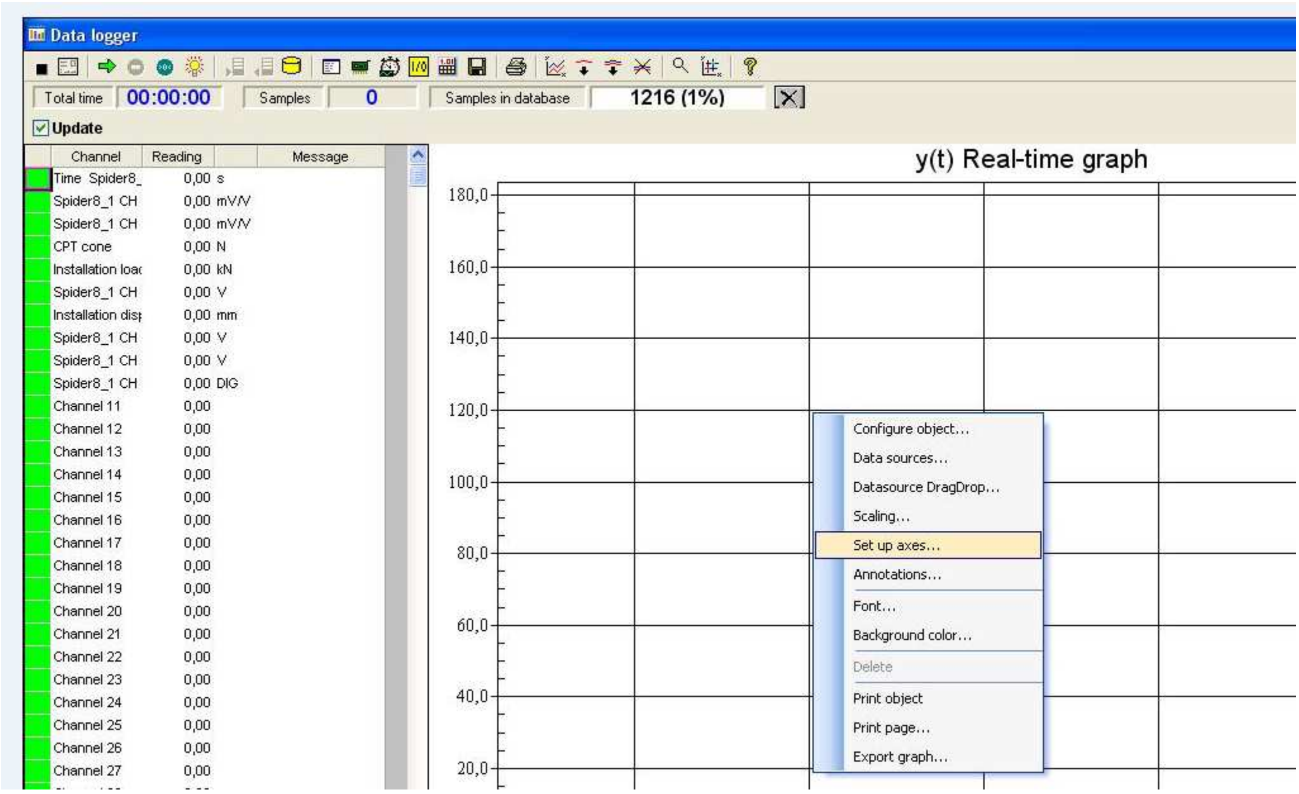


Figure 6.6. 'Data Logger' window: **'**Set up axes…' from the plotting area

For starting the measurements, press the green arrow in the menu bar of 'Data logger'. When the desired depth is achieved, stop the test by pressing the red button 'Stop' in the menu bar of 'Data logger' next to the arrow symbol. A new window pops up asking if the measurements should be saved. Say 'Yes' and then in a new window that pops up, chosen the localization for saving file, choose the two channels that should be saved along with the time (channel 'Time' is always saved automatically). Choose export format as 'ASCII + Channel information'.

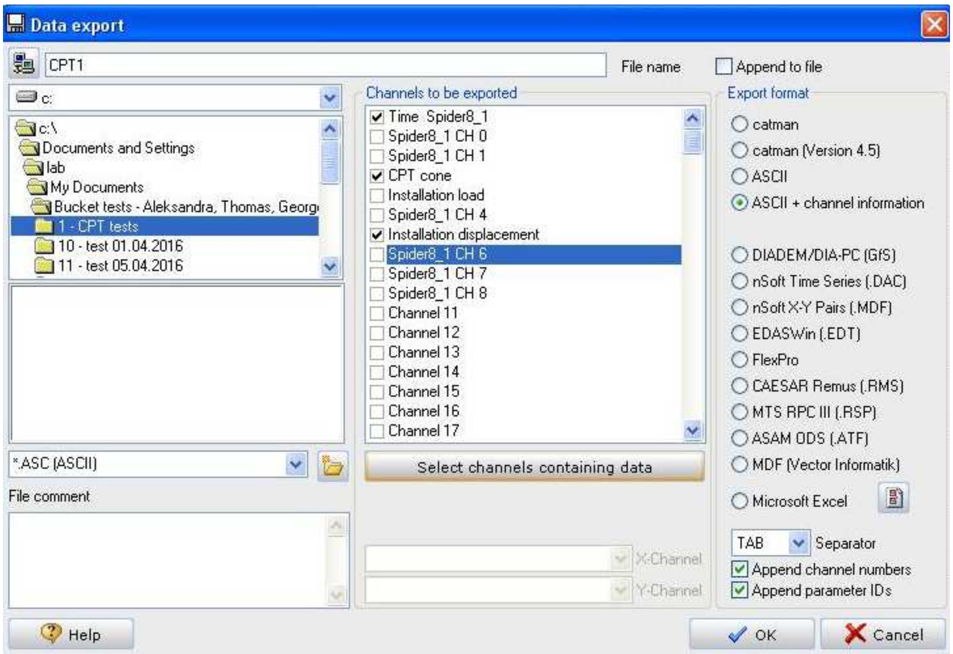


Figure 6.7. Saving data for CPT procedure

7. Installation of the beam on the outer boundary

The beam with pressure transducers is installed on the outer boundary of sand box, see Figure 3.1. (7) and Figure 3.5. The changes in pore pressure can be measured during installation and uninstallation procedure for the bucket foundation model.

The beam is cleaned before installation from any sand particles on it. The pipes attached to the beam are cleaned with the air piston (pipes at which ends the pore pressure is measured). REMEMBER! Unscrew the transducers from the pipes before pressing the air into the holes to avoid damage.

Prepare the working platforms, as the beam is installed at the edge of sand box. Put two aluminum bars (number 5 and 6) on the aluminum frame of sand box. Remember that numbers from beams and frame indicate the correct position.

(a) (b)

Figure 7.1. (a) Air piston and (b) aluminum beams set as a working space for beam installation

The pressure transducers are connected again to the pipes and must be saturated. The beam must be submerged in the black tank filled with water. Saturation is made by sucking the water through pipes to the valves of pressure transducers by using a syringe. Valves might need to be closed and opened couple of times, as long as we can see that there is no air in plastic pipes. At the end valves are closed and they are kept closed during installation. The sensors and all cables must be above water and a care must be taken not to disturb them during this procedure.

For beam installation the hydraulic piston is used. The piston must be unscrewed, moved to the desired position at the edge of the sand box, and screwed again. Beam with pressure transducers is screwed to the piston head. The pressure transducers are connected with a cable to the connection box fixed to the loading frame, just above beam position. The beam is slowly installed as a displacement controlled. Use the yellow controller to install the beam, till the depth where connection to the steel pipes is still visible.

(a) (b)

Figure 7.2. (a) beam with pore pressure transducers; red arrows indicated the maximum installed depth, (b) installed beam

8. Installation of bucket foundation

The installation can be performed with the use of suction or with the use of force.

8.1. Installation with suction

1. Water level in sand contained must be raised to around 10cm above soil surface. The soil should not be loosened during this procedure and therefore the water is slowly poured from the top. A thin plane is gently put on the soil surface and the hose connected to the water tank is put on the plate. The hose can be clamped on the frame to prevent the end of the hose from moving.

Figure 8.1. A plate and a hose used for raising the water level in sand box

2. The bucket model is cleaned from attached sand. The pipes from pore pressure transducers are also cleaned with the use of air piston. REMEMBER! Unscrew the transducers from the pipes before pressing the air into the holes to avoid damage.

3. The pore pressure transducers must be saturated. The bucket model is lifted by crane. Remember safety rules while using crane, see chapter 2. The bucket is submerged in black tank filled with water. The bottom of the bucket lid must be submerged, because one of the transducers is situated just below the lid. Cables and sensors must be above water level. All 6 transducers are saturated. The procedure for saturation of pore pressure transducers is described in chapter 7.

Figure 8.2. The bucket model lifted by crane

4. A working platform must be prepared on the frame of sand box. Aluminum beam no.7 and no.8 are used and the wooden plates are place on the beams. The hydraulic piston is moved to the center position on the loading frame and fixed with four bolts, two on each site. The head of piston must be changed as the installation is performed as a ‘force control’. The setting of hydraulic motor must be set properly, see section 3.3. The change of the head is required if the force during the test must be recorder. The bucket model is moved with a crane under the loading frame and set on the wooden plates. It cannot be placed directly under the piston head by crane, so when the bucket is unlocked from the crane, it is moved manually to be situated right under the piston. The connection piece is fixed to the loading cell/head of the piston, and the bucket is fixed to the connection piece. The bucket is pulled up using the yellow controller and the working platform can be removed. The bucket is lowered to the close vicinity of soil surface, to shorten the time of the installation procedure.

Figure 8.3. Head for hydraulic piston that is controlled by force

5. Connect the pressure transducers top the connection box fixed to the loading frame. Each transducer has a number and they must be correctly fitted to their positions to have desired measurements. As example a cable no.7 is connected to the socket with a name ‘CH6-7’ on the connection box.

(a) (b)

Figure 8.4. (a) cables connecting pressure transducers with a connection box and (a) connection box

6. Fix the displacement transducer to the plate perpendicular to the two parts of loading frame, see picture below. Connect the cable from the displacement transducer to the socket with a name ‘WS10-2’ on the connection box. Attached the string of the transducer to the bucket lid vertically with respect to the bucket. Ensure that the displacement transducer is working correctly by pulling it and checking the signal in ‘Catman’. The signal in the program must be green.

Figure 8.5. Displacement transducer clamped to the loading frame

7. The bucket foundation is first installed with the force to simulate a self-weight penetration. The bucket must be however fixed to the piston all the time, so the self-weight is applied as a force. The self-weight of bucket is 204kg. The process of self-weight installation is considered to be finished when no more further penetration is observed. The value of the force on the control panel from the hydraulic motor is set to be 0. This means that the force equal to the self-weight is applied.

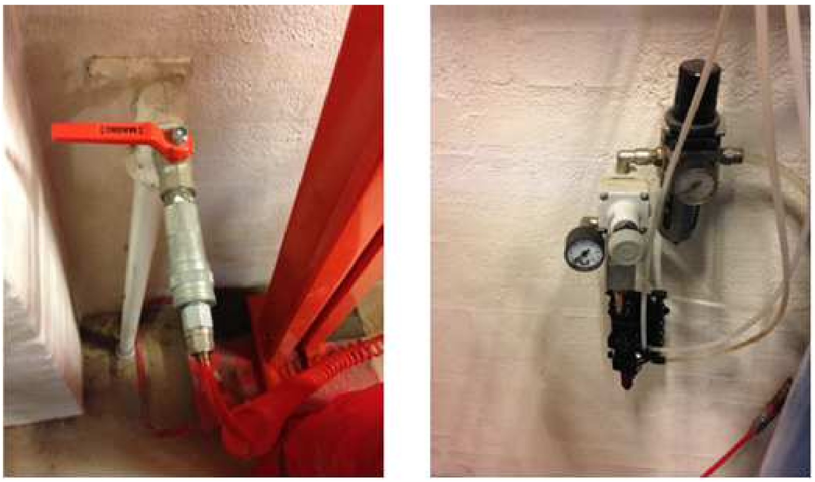
Figure 8.6. Control switchboard for the hydraulic motor: force set to 0.00.

8. The valves on which the suction is applied are installed on the bucket lid. The valves must be open all the time. The blue vacuum system is connected to the valves on bucket lid through the plastic pipes.

(a) (b)

Figure 8.6. (a) Valves that are mounted to the lid and (b) connected pipes to the fixed valves on the bucket lid

The pump is opened by switching the handle on its left side. Also the valve from the compressed air must be opened to start the vacuum process. The value of pressure can be read from the manometer, however, as the manometer is really sensitive and some of the pressure can be lost through the hoses system, the precise value of applied suction is read from the pore pressure transducer situated under the bucket lid. The value of pressure from the vacuum must be controlled during the test, as it might decrease/increase with the time. During the installation the suction is increased by the gray handle situated on the left side of the vacuum container.



(a) (b)

Figure 8.7. (a) The valve to the compressed air system and (b) control system fpr applied pressure

Do not exceed the critical suction to prevent any piping problems (Koteras et al., 2016). The water that is sucked through the pipes should be refill. During the test the level of water must be controlled and water must be added if the water level is falling down. Again, when adding water, the soil cannot be disturbed. The level of water in the blue vacuum tank must also be controlled. When the level reaches its maximum level, the test should be stopped and started again when the water from the blue tank is removed. The suction is closed with the valve situated on the front of blue tank. Also the valve from compressed air must be closed before removing the water. Suction should be still applied when the bucket is fully applied to make measurements of fully developed seepage.

9. The results are saved and then the set-up is prepared for CPT after installation. The piston is disconnected and pulled up. The force control head is changed back to the displacement control head. The valves from the bucket lid are disconnected. CPT tests can be performed for desired localizations. Follow the procedure described in chapter 5.

8.2. Installation with force

1.-3. Steps are the same as in previous section.

4. The 'displacement control' head for the hydraulic piston is used. Settings for the 'displacement control' piston are described in section 3. 3. Set a penetration ratio on the control switchboard for the hydraulic motor to be 0.13 [mm/s]. A working platform is place on the frame. The bucket is placed close to the center and pushed manually, so it can be fixed to the piston.

Figure 8.8. A 'displacement control' head for hydraulic piston

5.-6. Steps are the same as in previous section.

7. Before starting the recording, place the bucket foundation close to the soil surface using the yellow controller. The tests starts from this place and should be recorded in 'Catman'. 4 valves on the bucket foundation should remain opened during the test.

8. Repeat step 9 from the previous section.

9. Uninstallation procedure

The uninstallation of the bucket foundation is performed with the use of overpressure. Different weights can be additionally place on the bucket lid to simulate bigger self-weight of the model.

1. The hydraulic piston is placed in the center position. The head used for the uninstallation must be 'force control' in order to record the force. The settings are described in section 3.3.

2. The bucket is fixed to the head of piston but not tightly. Around 5 cm space between head and bucket connecting part should be left. The uninstallation is performed with the use of overpressure from

water only and the piston is only used for stabilization. The space between the bucket and piston must be kept during the whole uninstallation process.

3. A hose connected to the water supply is screwed on one of the middle valves on the bucket lid. A water supply is opened to insert slowly water inside the bucket, until the air of the other valves on the bucket lid is out. Then all three valves are closed instantly along with the water supply.

4. If required for the test, additional weight is put on the top of bucket lid.

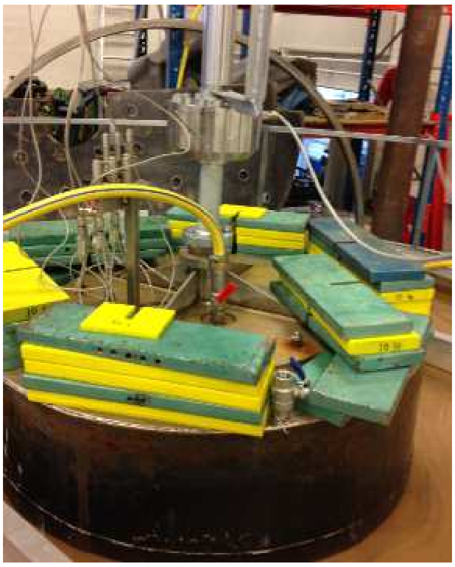


Figure 9.1. The bucket foundation during uninstallation with additional weight on the lid

5. Test is ready to be started. Start the recordings and start the test by opening the water supply to its 50% capacity. During the test the piston is controlled manually with the yellow controller. The piston can never touch the connection piece on bucket, as this will affect the results. Therefore, the piston is moved constantly upward when the bucket is pushed up as an effect of water pressure under the bucket lid.

6. The recording should stop when the water breaks under the bucket skirt. The additional weight is taken out from the lid carefully and the bucket is uninstalled and moved away from the sand box with the use of crane.

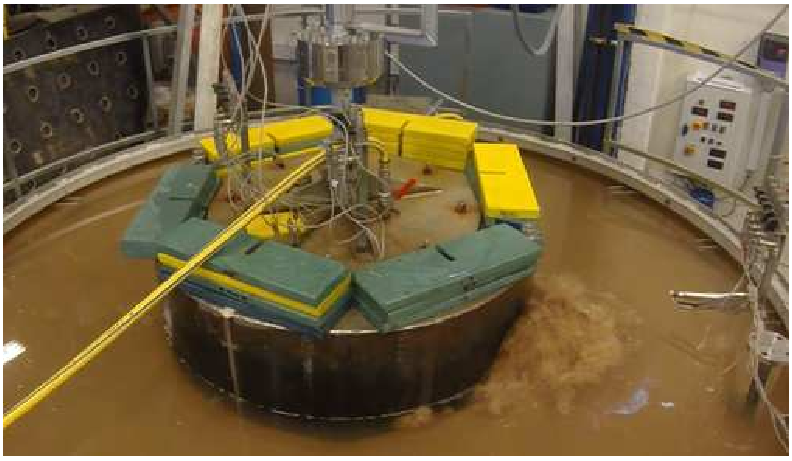


Figure 9.2. The break of hydraulic seal under the bucket at the end of uninstallation process

10. Data acquisition during installation and uninstallation procedure

The signals for the installation/uninstallation procedure are acquired in 'Spider8' and 'MGC Plus' and both must be read in software 'Catman'. Such a configuration is problematic because 'Spider8' and 'MGC Plus' cannot proceed when connected to one computer. Another computer must be used for the procedure. The 'MGC Plus' device should be connected to the stationary computer situated at the laboratory desk. The 'Spider8' device should be connected to the additional laptop with USB connection. Pore pressure transducers and the displacement transducer are connected to the 'MGC Plus' device, whereas the loading cell recording the force is connected to 'Spider8'.

Settings of the software for each device are described in this section. On the laboratory computer 'Catman Professional' is installed, and on the laptop 'CatmanEasy' is installed.

Recordings from 'Catman Professional'

The program is opened and it can be scanned in order to find data acquisition device. Open 'I/O Definitions' and press on 'Device scan'. Then all setting should be adjusted. For the installation procedure an '-.IOD' sheet has been prepared, which includes all required settings. The file name is 'thg_setting_pres.IOD'. It should be open in 'I/O Definition'. If pore pressure transducers are calibrated and calibration factors differ significantly, new settings are required, see Appendix C.

In 'I/O' Definition' all channels working are displayed with green arrows. A continuous reading can be used for checking if the channels record correctly, see Figure 6.3. All channels are zeroed clicking on the button marked in the following figure. In the column 'Status/Reading' an 'OK' icon pops up with a value really close to zero. If value in this column differs still from zero, click 'Zero' button again.

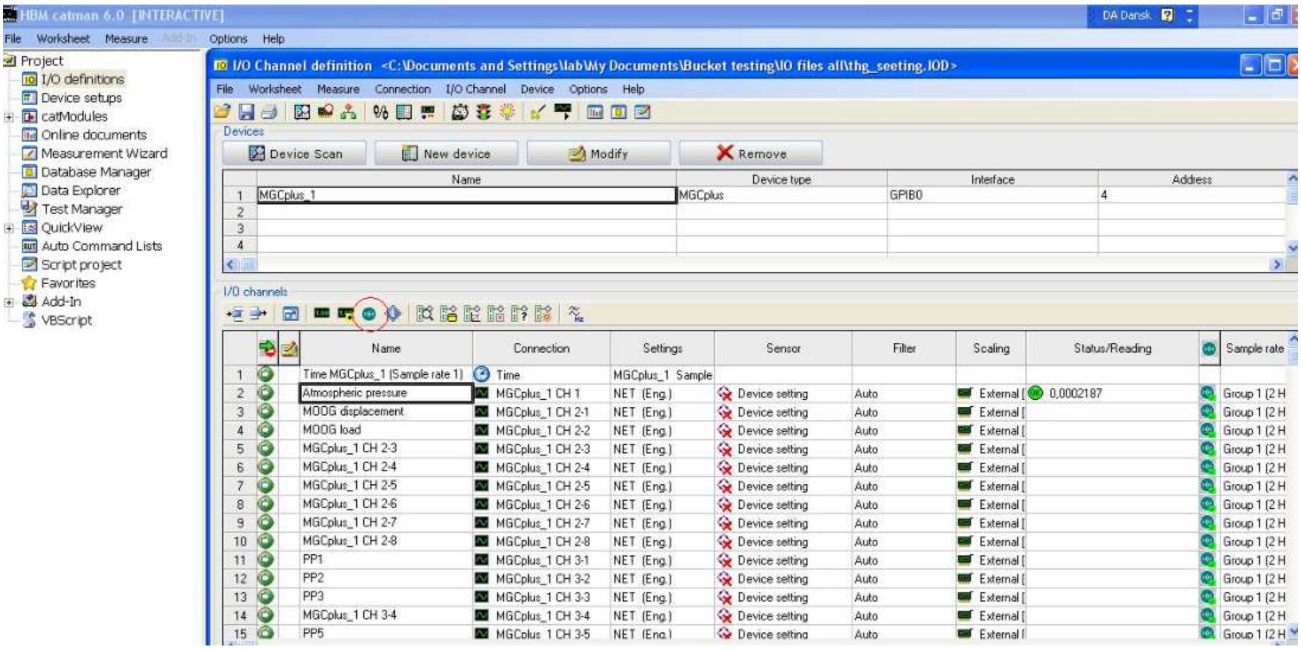


Figure 10.1. Active channels for Installation procedure and zeroing procedure in 'Catman Proffesional'

Channels required to work for the installation/uninstallation procedure are as following:

- ✓ Atmospheric pressure
- ✓ PP1 – PP6 from the pressure transducers on the bucket lid
- ✓ WS10k2 from the displacement transducer
- ✓ Beam tip, Beam middle, Beam top from the pressure transducers on the beam

The records are made in 'Data Logger'. The procedure for recordings is described in chapter 6.

Recordings from 'CatmanEasy'

The program is opened on the laptop device. Active channels will be seen automatically. The name of the file with settings is 'CPTsetupTHG.MEP'. The setup is the same as for CPT procedure, recording the displacement and force of the loading cell. The channels active for this procedure are 'InstalForce' and 'InstalDispl'. Channels should be zeroed by clicking on the green button in the menu bar called 'Execute'. In the column 'Status/Reading' an 'OK' icon pops up with a value really close to zero. If value in this column differs still from zero, press on 'Execute' button again.

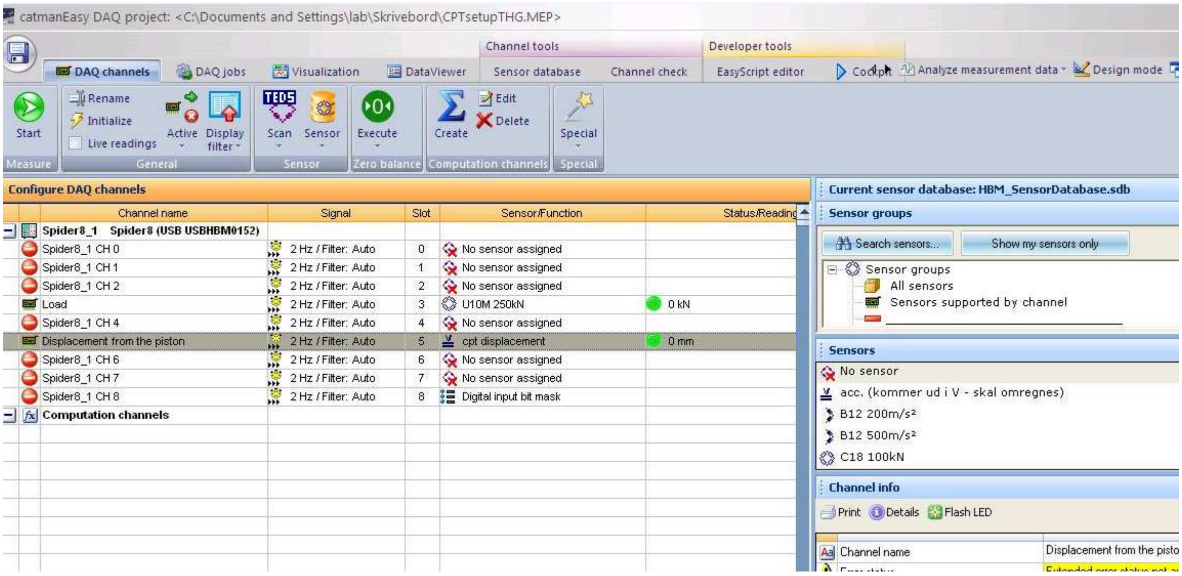


Figure 10.2. Active channels for installation procedure in 'CatmanEasy'

Recording starts by clicking on the 'Start' button in the menu bar. After the test is finished the 'Stop' button is pressed and results should be saved.

11. References

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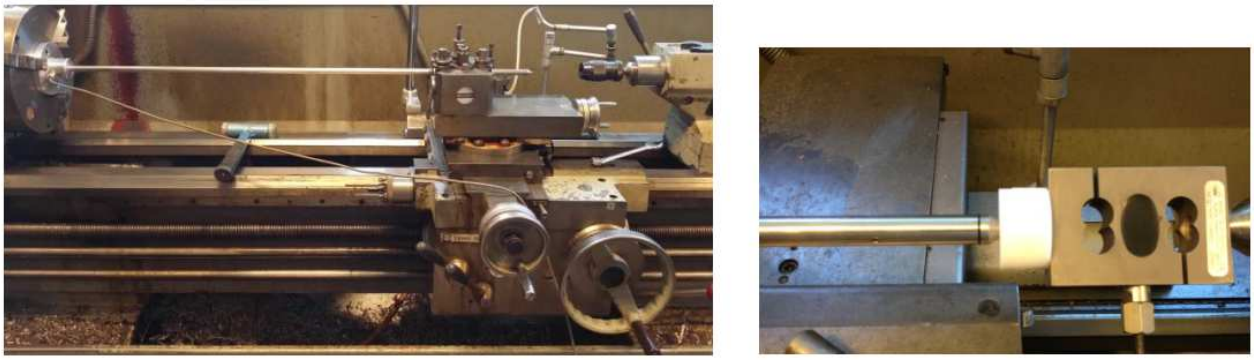
Appendix

A. Calibration of small CPT device

Calibration process should be performed under supervision of technicians in the laboratory. A special lathe device is used for this purpose. A small white, rubber block is used for protection of the cone. It has dimensions to fit perfectly the cone. A force transducer used here gives a signal of 5 [kN] = 2 [mV/V]. It is inserted between the cone and bench and it measure a force on the cone when the lathe is moving and pushing the cone. The device is connected to the laptop and signals are recorded from both force transducer and CPT device in 'Catman'. Re-load the force a couple time for validation.



(a) (b)

Figure A.1. A lathe device used for a calibration of cone: (a) a device with locked cone of CPT device, (b) a rubber block and force transducer used for the calibration (Thomassen, 2015a)

A calibration factor can be found by plotting the results recorded during the calibration process. A CPT gives a signal in [mV/V] and the force transducer gives a signal in [N]. A linear fitting should give a calibration factor.

After calibration, if calibration factors differ significantly and must be changed, a device must be set. This is done in 'Catman' software. In the 'Project' go to the 'Device Setup'. It must be ensure that the measuring range is set to 12 mV/V. Green color of reading indicates that the signal is read correctly.

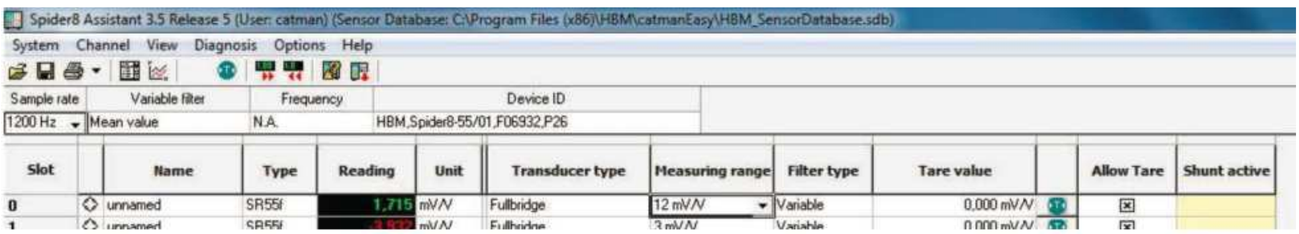


Figure A.2. 'Device Setup' window

Next, when returned to ‘I/O Definitions’ and in ‘Scaling’ column choose ‘User’ and insert a linear variation between the signal in [mV/V] and signal in [N] found through calibration process.

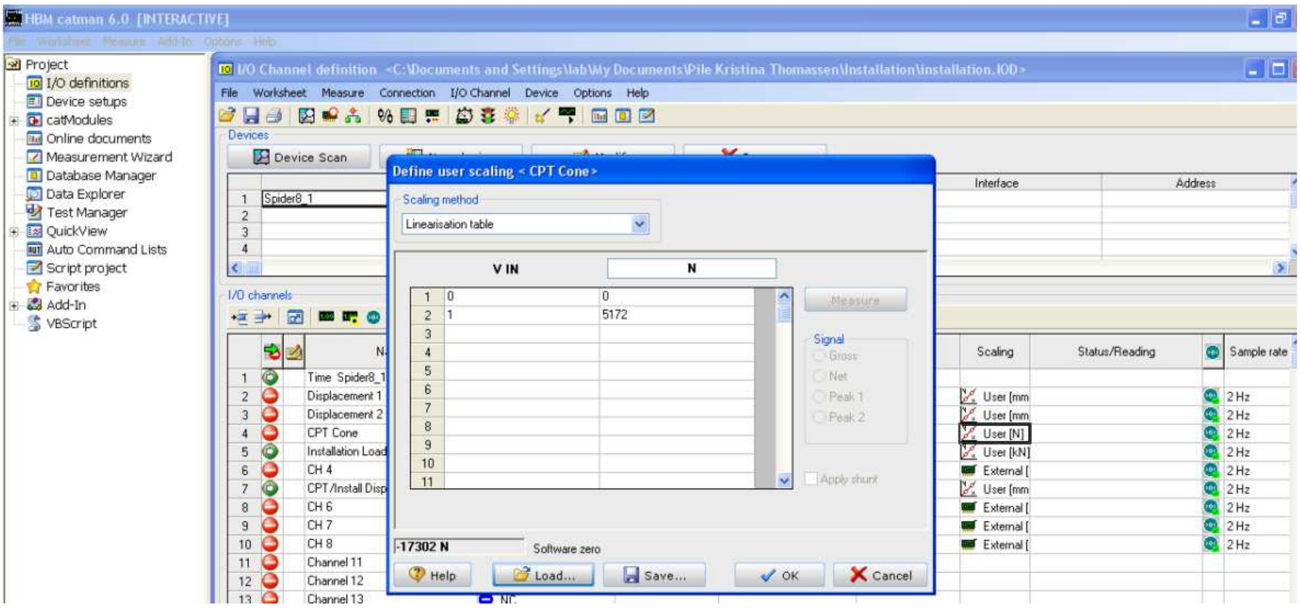


Figure A.3. ‘Define user Scaling’ for ‘CPT Cone’ channel

B. Parameters of soil derived from CPT results

During the penetration of cone three measurements are recorded:

- ✓ time, t [s]
- ✓ depth, d [mm
- ✓ cone resistance, q_c [N].

The soil parameters are based on CPT results and the drained triaxial tests results of Aalborg University Sand No. 1, see Table 3.1. in chapter 3. The formulation for soil parameters are derived by Ibsen et al. (2009).

The relative soil density, I_D, is based on the cone penetration.

$$I_D = 5.14 \cdot \left(\frac{\sigma'_{v0}}{q_c^{0.75}}\right)^{-0.42} \quad \text{(B.1)}$$

where

q_c	Cone penetration resistance from CPT [N]
σ'_{v0}	The effective vertical stress acting on soil [kN/m^2]

The effective vertical stress can be calculated from the effective soil unit weight, γ', and the measured depth. This is possible knowing the soil parameters derived from traixial tests.

$$\gamma' = \frac{d_s - 1}{1 + e_{insitu}} \cdot \gamma_w \quad \text{(B.2)}$$

where

e_{insitu}	In situ void ratio [-]

The relative soil density from the definition is dependent on the void ratios, see following equation.

$$I_D = \frac{e_{max} - e_{insitu}}{e_{max} - e_{min}} \quad \text{(B.3)}$$

As in situ void ratio is required to derive both, the relative density of soil and the effective unit weight, iteration calculations are performed, where value of in situ void ratio starts at its minimum value.

The expression for friction angle, φ_{tr}, and the expression for dilation angle, ψ_{tr} , are derived from traxial tests, but they require also the results of CPT.

$$\varphi_{tr} = 15.2° \cdot I_D + 27.39° \cdot \sigma_3'^{-0.2807} + 23.2° \quad \text{(B.3)}$$

$$\psi_{tr} = 19.5° \cdot I_D + 14.86° \cdot \sigma_3'^{-0.09764} - 9.946° \quad \text{(B.4)}$$

where

σ_3'	The effective horizontal stress acting on the soil [kN/m^2]

As the test are performed with much smaller overburden pressure comparing to the procedure used by Ibsen et al. (2009), a reference pressure of 5 [kPa] is used in both formulation, $\sigma_{3,ref}' = 5$ kPa.

C. Calibration of pore pressure transducers

A calibration device is used to calibrate the pore pressure transducers. It contains a water tank connected to the pressing mechanism. The device should be connected with the measuring box through the reference transducer and the box is connected to the laptop where measurements are recorded.

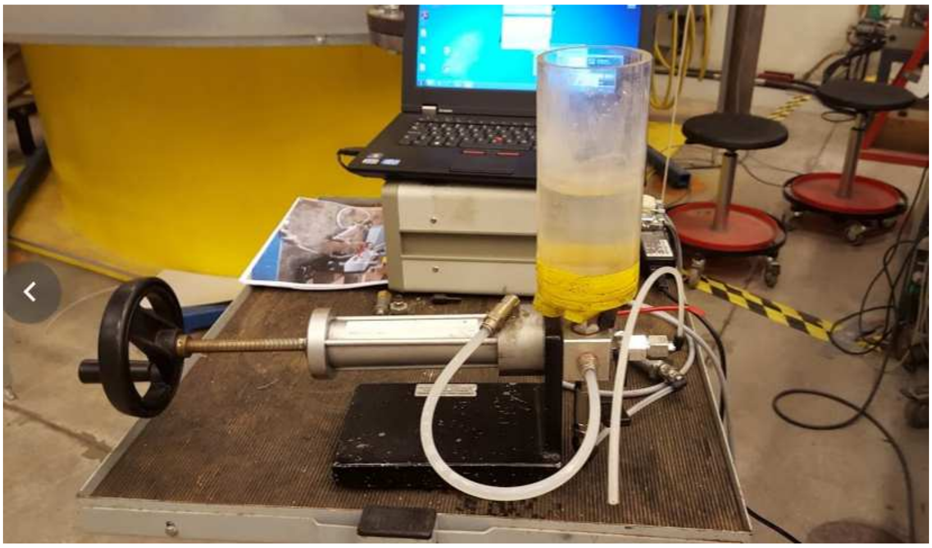


Figure C.1. Mechanism used for pressure transducers calibration

(a) (b)

Figure C.2. (a) A reference transducer and (b) Connections on the measuring box: charger, laptop and reference transducers connections

On the laptop a software called 'MVD 2555' is opened. A window pops up and a 'Setup' is pressed. A saved setting should be loaded: File -> Open setup -> correctsetup1000_2.0.MVD.

There are three valves in the system: one connected to the small water tank, one connected to reference pressure transducer and the last one should be connected to the pressure transducer that is calibrated. Pipes must be filled with water and any air bubbles must be avoided. The connection of water from the tank must be opened and the water must be pressed into the pipes.

The transducer should be situated close to the device and also close to the acquisition devices. The signal from the reference transducer is recorded in the laptop in [kPa]. At the same time the calibrated pressure transducer gives the signal to 'Catman' on the computer in [mV/V] for the same pressure. This can be seen in 'Catman' software in 'Device Setup' and next in 'Input characteristic'.

Before calibration the device should be zeroed in the software. Only water valve connecting the water tank is open. For measurements two other valves are also open and the water is pump to create the pressure. Measurements must be done for at least two values of pressure. When desired pressure from reference transducer is achieved, a 'Measure' button in 'Catman' is pressed to see the signal in [mV/V].

Calibrated values are given in the following table. However, the procedure must be repeated for new test campaign.

Table C.1. Results of calibration procedure for transducers on the bucket model

Number on the transducer	Number on the bucket	Channel in Catman	Signal in [mV/V]	Signal in [kPa]
2	5	CH 6-5	2,7318	0
			2,7411	20
6	4	CH 6-6	2,74219	0
			3,29694	20
7	7	CH 6-7	2,73746	0
			3,29327	20
2	2	CH 6-2		0
				20
3	3	CH 6-3	2,68502	0
			3,2398	20
1	1	CH 6-1	2,21655	0
			2,68672	20

Table C.2. Results of calibration procedure for transducers on the beam

number on the transducer	number on the beam	channel in Catman	Signal in [mV/V]	Signal in [kPa]
3	1	CH 7- 1	2,85439	0
			3,41295	20
4	2	CH 7-2	2,77825	0
			3,374	20
5	3	CH 7-3	2,721	0
			3,276	20

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