88mm Self-Boring Pressuremeter (SBPM) Method Statement

Testing from a Rotary Drilling Rig via rods

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Table of Contents

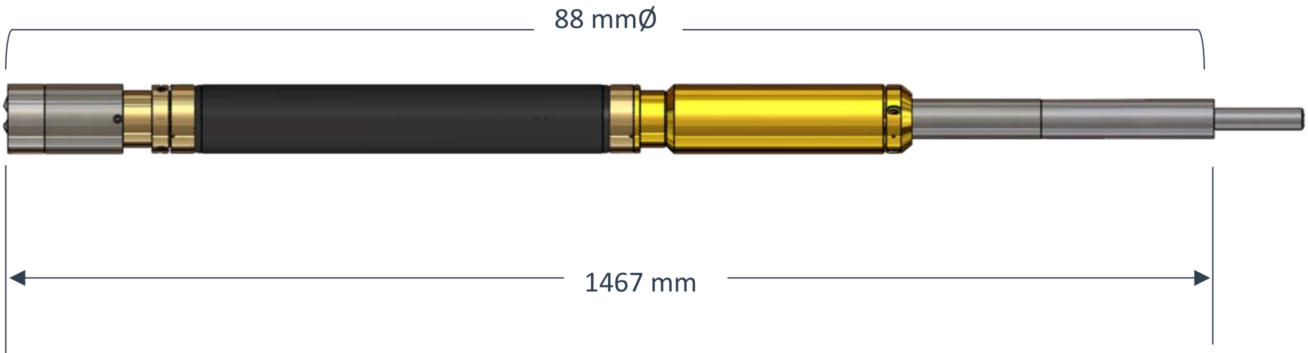
1.0 Equipment

A Cambridge Insitu (CI) manufactured Self-Boring Pressuremeter (SBPM) with 100m umbilical, Hughes Hardware, electronic interface unit and high pressure control panel (HPCP).

Bought/not-bespoke equipment is also provided including double drill rods, 2 x 12l air cylinder, pneumatic hose and site laptop. Emergency First Aid kit (normally stored inside work vehicle), plant drip tray and spill response kit for petrol driven air compressor and emergency fire extinguisher suitable for petrol/diesel fires (normally stored in work vehicle).

1.1 System Diagram

All units are millimetres. Overall length is indicative only as it depends on final sub arrangement.



Please see the SBP specification sheet for further instrument specific details at www.cambridge-insitu.com

Figure 1.0. CAD render of an 88mm SBP configured without subs or rods.

2.0 Drilling Requirements

1. The borehole should be advanced to 0.5 metres above the proposed test location and should be clear of any stones or obstructions, as discussed on site between the geotechnical engineer/pressuremeter engineer.

2. The SBPM is then lowered down the borehole on its own rods using the drilling rig, before drilling the SBPM at least 1.0 metre into the ground. Drilling can take from ten minutes to an hour or more depending on test depth and material conditions.

3. It is important to note that for successful self-boring the rotary coring rig must be capable of producing a downward force not less than 2 tonnes. This is to overcome the skin friction on the outside of the self-boring pressuremeter.

4. When operating under the main contractor’s rotary rig our instrument (and rods) can be fitted with an NWY, HWY or a 2⅜” API Regular Box thread sub at its top. The necessary sub to fit other rig threads can be supplied but we must be consulted well in advance to produce any necessary adapters.

5. When operating under a rotary rig our instrument requires an absolute minimum of 1.60 metres between the bottom of the pin thread on the rotary rig and the top edge of the casing in the hole. It may be necessary to raise up the whole rig to achieve this distance.

6. We can use flushing fluids other than water but we should be consulted first if this is planned.

7. It is very desirable that we discuss the working procedure with the actual drilling sub-contractor before the contract starts and arrangements should be made for us to do this as soon as possible after the award of the contract.

3.0 Mobilisation of SBPM

1. Prior to the project, the pressuremeter is calibrated. This includes transducer calibrations for each individual arm as well as the total pressure cell and pore pressure cells. The overall straightness of the pressuremeter is measured on a custom-made jig. Further to this, the pressuremeters' system compliance is measured to account for any deformation of the probes body itself under pressure. Finally, the individual membrane fitted to the probe is calibrated, allowing for a correction to made in the live test. In the event of a membrane being replaced, the new membrane is also calibrated. All calibrations (with the exception of straightness) can be completed whilst on site if necessary. The Instruments' pre-project calibrations and any other calibrations undertaken will be included in the report.

2. The pressuremeter and the associated equipment shall be brought to site (normally in a van) ready for testing. If four-wheel drive is essential, it can be provided but we must be consulted before agreeing prices. The van must be parked as close as possible to the drilling rig, if this is not possible then we must be consulted before hand to make other arrangements.

3. The SBPM is to be assembled on-site on the supplied A-frame, with the electronic interface box, HPCP and operators site laptop are to be set up in a sheltered and dry location. Compressed air cylinders (charged to >15MPa) are also to be set up, strapped upright to prevent toppling movement where possible, but at a suitable distance to the operators HPCP as to allow for pneumatic hose length.

4. Following successful set up of the instrument, pre-test zeroes are to be taken using the electronic interface and laptop (using supplied software). These data readings denote the instruments recording values at atmospheric conditions and serve as a record of the instruments condition pre-test.

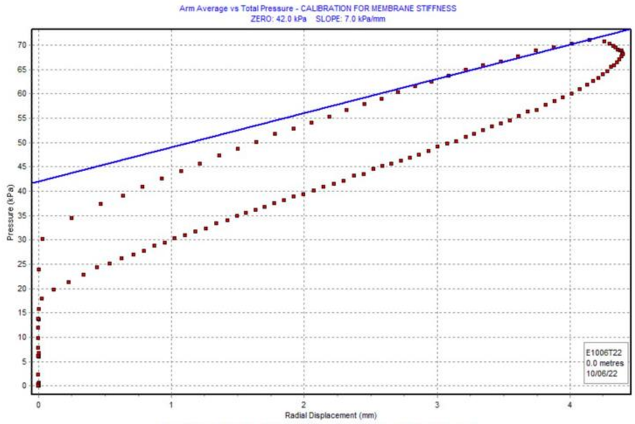


Figure 2.0. SBP membrane stiffness calibration, determining membrane slope.

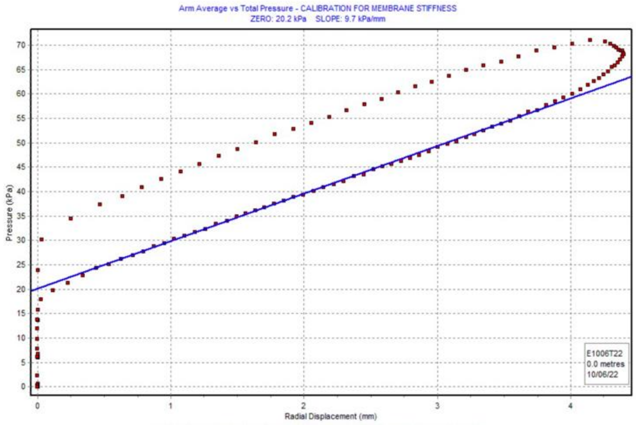


Figure 3.0. SBP membrane stiffness calibration, determining membrane zero.

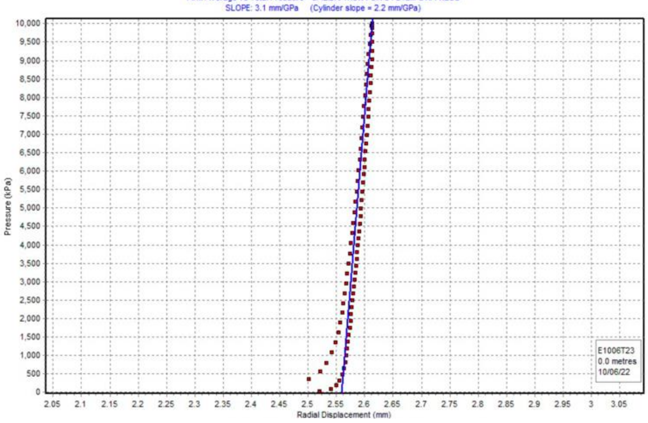


Figure 4.0. SBP system stiffness calibration, determining the entire systems deformation under stress.

4.0 Methodology for Operating Self-Boring Pressuremeter (SBPM)

The SBPM is intended to be inserted into the ground for testing by the action of drilling its own pocket to test. This is done via the cutting shoe and internal drag bit or rock roller as applicable. The SBPM operates with an inner and outer rod setup, with the inner rods providing drive/feed from the drill rigs head unit to the bit and the outer rods acting as an annulus for the flush return as well as physically joining the SBPM and the drill rig.

1. The SBPM has an umbilical hose/cable which should be taped to the drill string at regular intervals, approximately every six metres. The instrument must be lowered to the foot of the borehole, and then advanced under the pressuremeter engineers' direction by 1m. it is intended that the entire expanding section to sit in a homogenous material. This can be decided via core samples or CPT data and is for the discretion of the pressuremeter engineer.

2. Once drilled into position a cavity expansion test is carried out lasting approximately 30 minutes before extracting the SBPM using the drilling rig. The borehole can then be advanced to 0.5 metres above the next test location. Casing should be added where necessary to ensure that the borehole remains stable and clear of obstructions.

3. The immediate results from the test are presented as a graphical plot (presented via software) of pressure (kPa) versus radial displacement (mm). These are direct measurements produced by the pressuremeter, accurate to $1x10^{-3}$mm and 1kpa. Therefore, these graphs illustrate the data collected presented without any post processing, save the corrections made by calibrations. Following the completion of pressuremeter testing on the project, the graphs and the data they contain are analysed to produce the post-processed final results and engineering values. These are included in a factual report deliverable.

4.1 Testing Procedure Overview

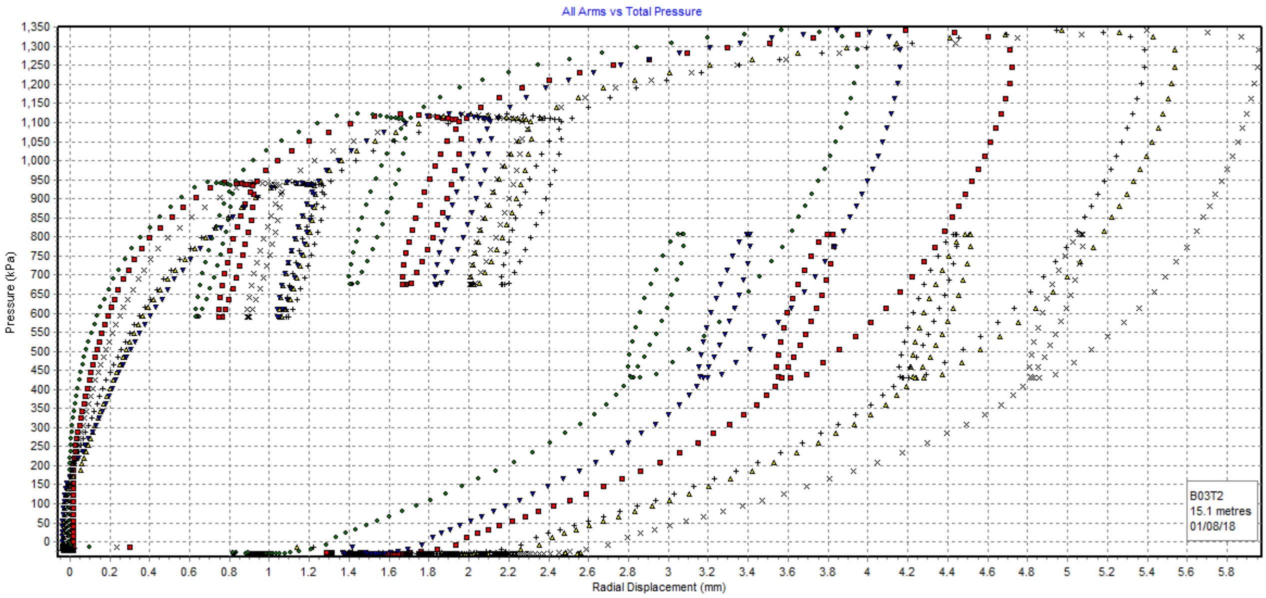
The steps involved in the testing procedure as outlined below can be seen graphically explained in the figures 5.0 and 6.0 below. (Note: these graphs are examples of this kind of test only).

To carry out a test the SBPM will be drilled to the required depth so the entire expanding section is to sit in a homogenous material.

1. The cavity expansion test should be stress controlled with pressure and displacement readings being recorded every six seconds.
2. Care should be taken over the first 0.5mm of the tests expansion to maximize data quality of the total insitu horizontal stress (P_0).
3. Unload/reload cycles should be taken once the level of stress has been raised high enough to overcome the total vertical pressure.
4. At least two unload/reload cycles should be taken at different levels of strain to provide the best possible data for shear modulus.
5. Unload/reload cycles may be taken during the loading and unloading phases of the test, at the discretion of the operator.
6. The pressure should be held briefly before each unload/reload cycle to ensure that material creep is at a minimum.
7. During each unload/reload cycle the pressure should be decreased by approximately one third of the starting pressure of the cycle.
8. Each cycle should consist of approximately ten data points for the unloading and loading phases, a total of approximately 20 points. The stress level should remain above the total vertical stress throughout each cycle.

4.2 Notes on Methodology

A pressuremeter test is defined as having taken place and being, therefore, chargeable when the pressuremeter has reached the correct depth with all transducers working and pressure has been applied to it. The greatest care will be taken in designing and conducting the test to gather the maximum possible quantity of useful data. If the ground conditions are such that the instrument membrane bursts prematurely the test fee remains payable.



Pressure hold before 1st unload/reload cycle to ensure creep is kept to a minimum.

Unload/reload cycle (2nd of two on the loading part of the test).

The unloading component of the test. The pressure is gradually reduced until reaching its initial stress-state.

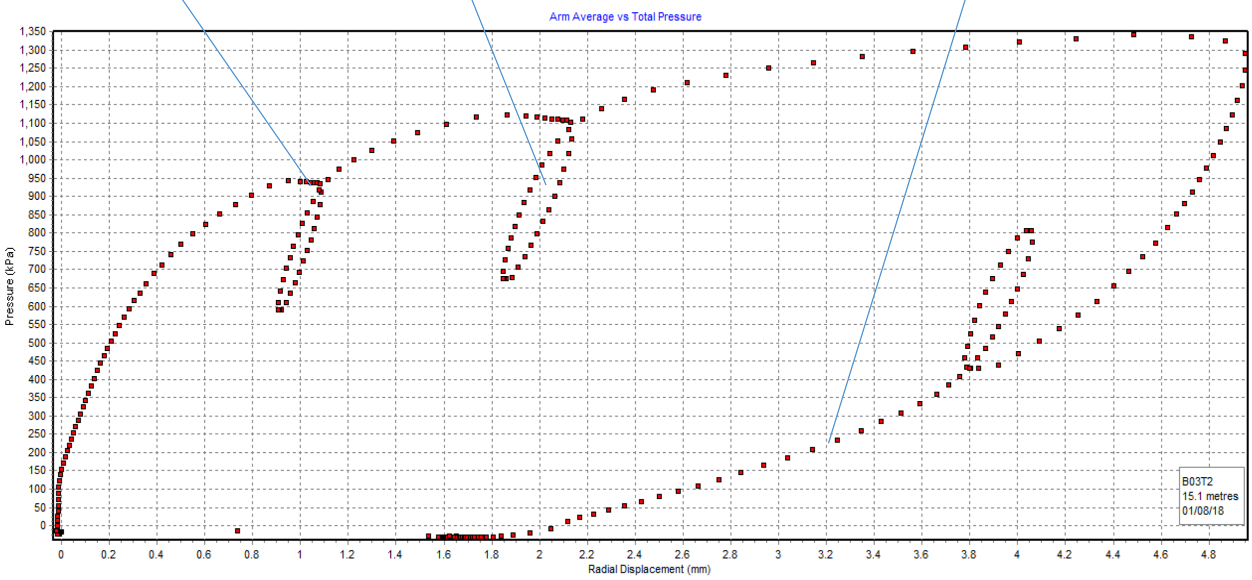


Figure 6.0. Data points as seen on software ‘Winlog’ during live testing. This plot illustrates the displacement data from the average of the six arms (x) against the total pressure in the probe (y).

5.0 Post Processing

Following completion of a successful test, the results on the graph displayed in figure 5.0 and 6.0 are processed using Cambridge Insitu Limited's in-house analytical software. An example of a typical test being analysed can be seen in this section. (Note: these graphs are examples of these analyses only and not a comprehensive list).

The pressuremeter loading curve can be solved directly using mathematical expressions for the expansion of a cylindrical cavity. The solution conventionally is quoted in terms of stiffness and strength parameters for the material, specifically shear modulus, shear strength or friction angle as appropriate, and the insitu lateral stress. A number of simplifying assumptions are made about the nature of the test and the ground. For example it is assumed that the material is fully saturated, homogenous, isotropic and behaving as a continuum that fails in shear only and that the length of the pressuremeter is great enough for the test to be modelled as a plane strain expansion.

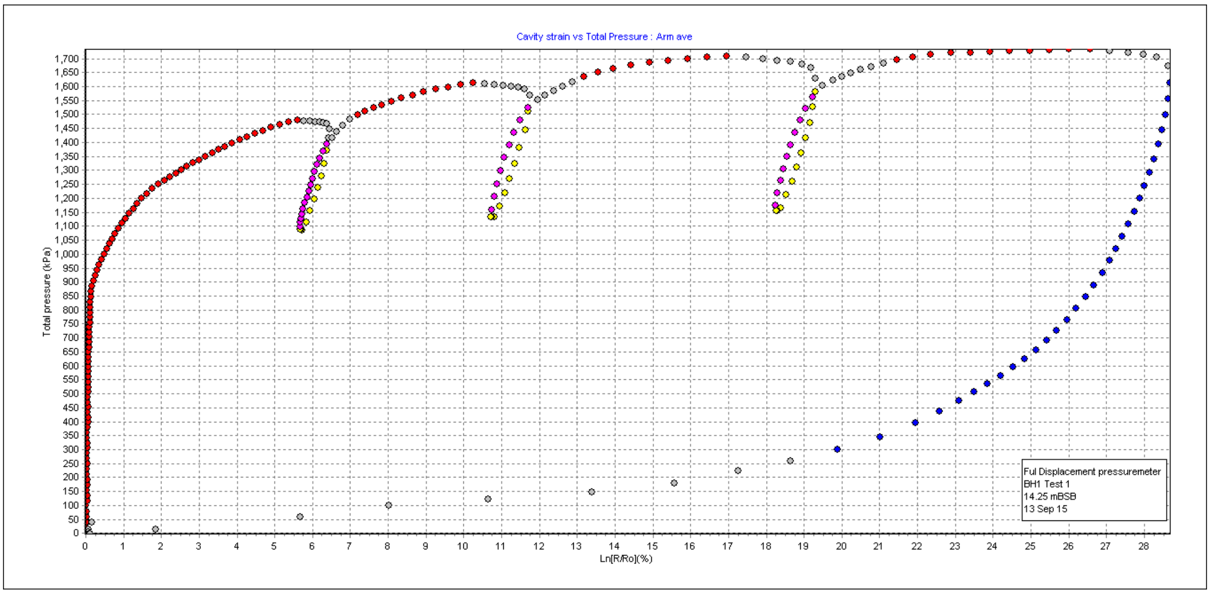


Figure 7.0. Data points as seen on software 'Winsitu' . This graph shows the plot of Cavity Strain vs Total Pressure (arm displacement average).

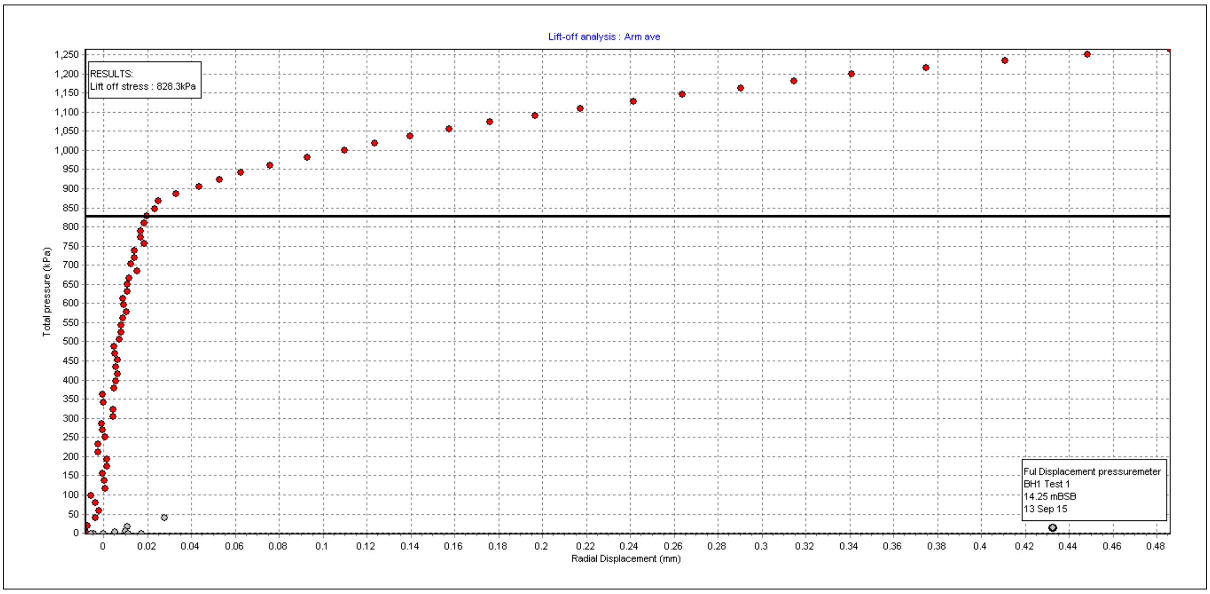


Figure 8.0. Data points as seen on software 'Winsitu'. This graph shows the plot of the Lift-off analysis.

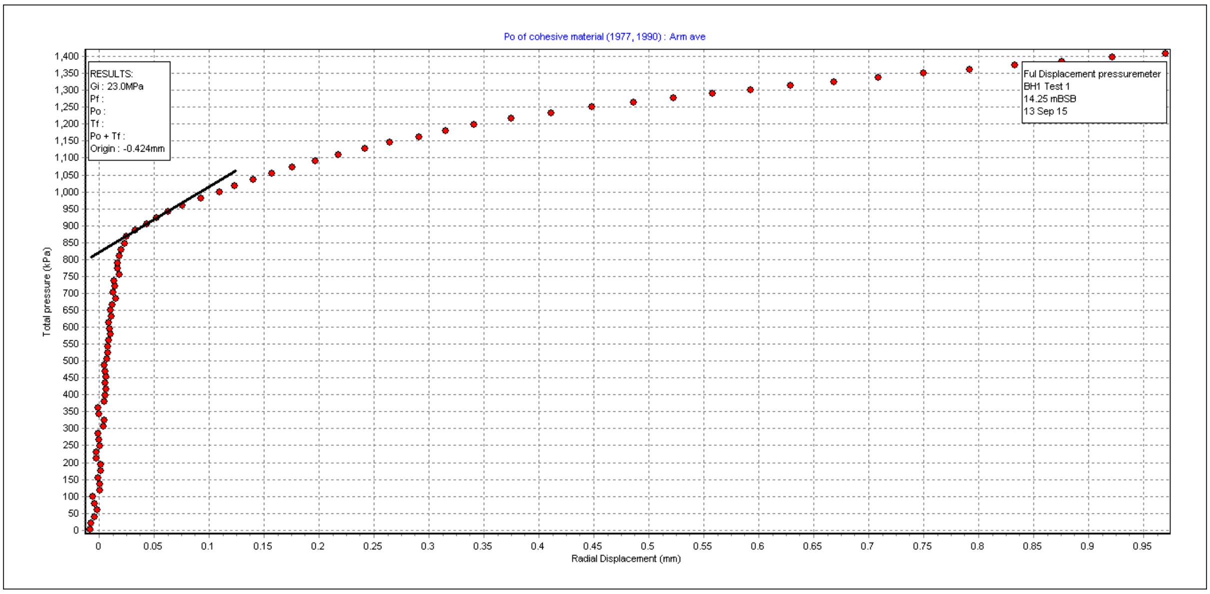


Figure 9.0. Data points as seen on software 'Winsitu'. This graph shows the plot of Undrained yield Arm Average.

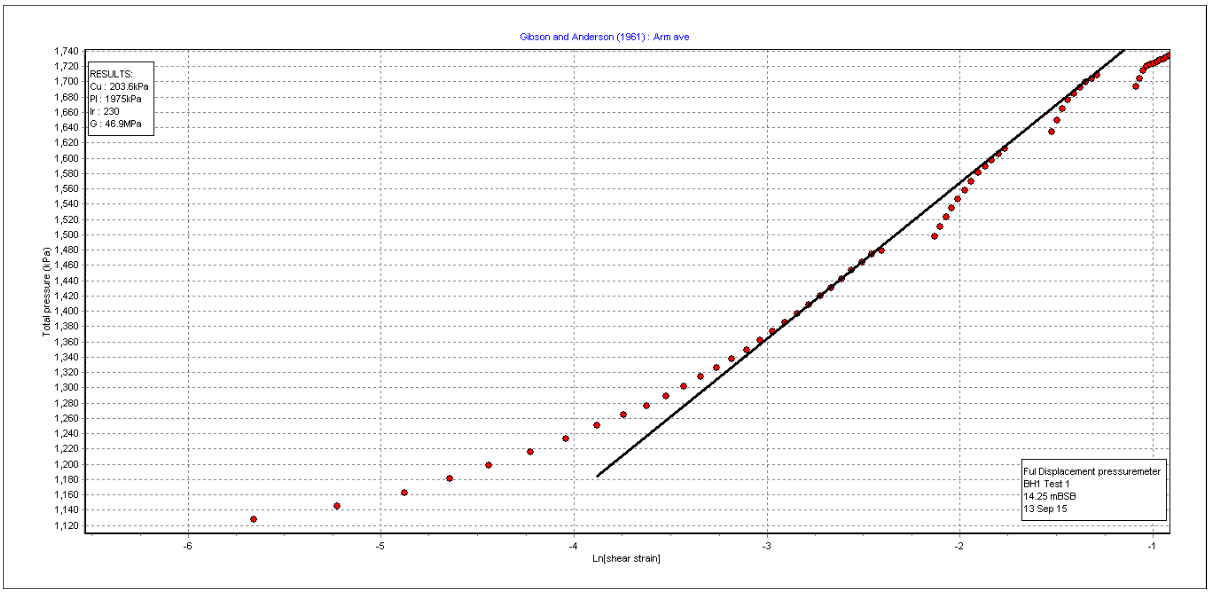


Figure 10.0. Data points as seen on software 'Winsitu'. This graph shows the plot of the Gibson and Anderson (1961) analysis.

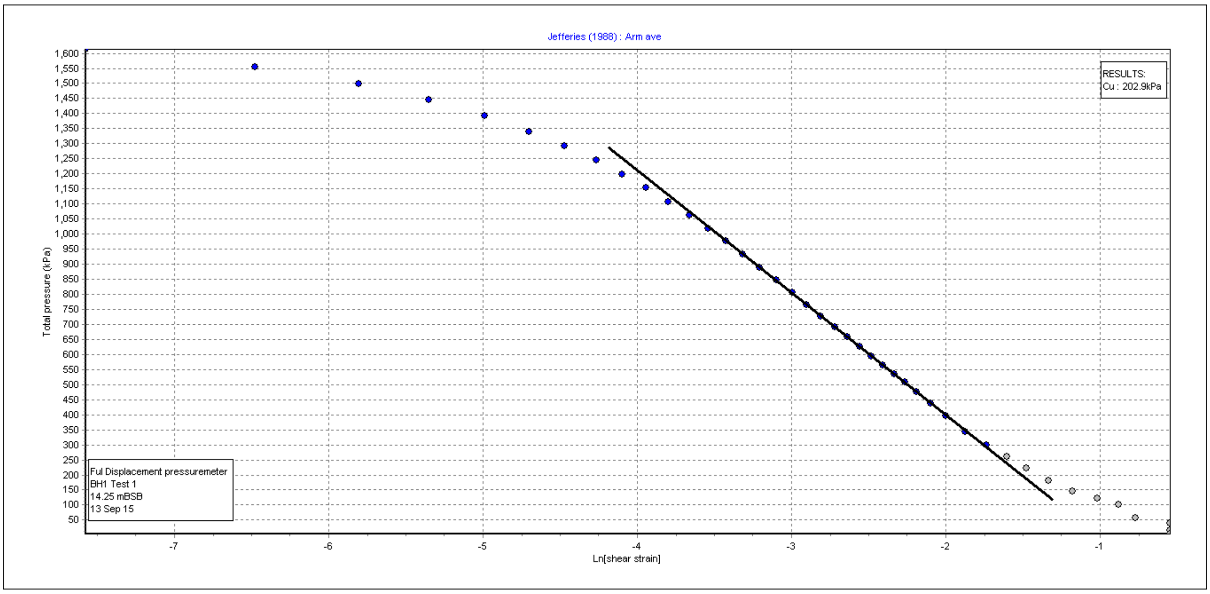


Figure 11.0. Data points as seen on software 'Winsitu'. This graph shows the plot of the Jefferies (1989) analysis. NOTE this analysis is based on the data from the unloading part of the pressuremeter

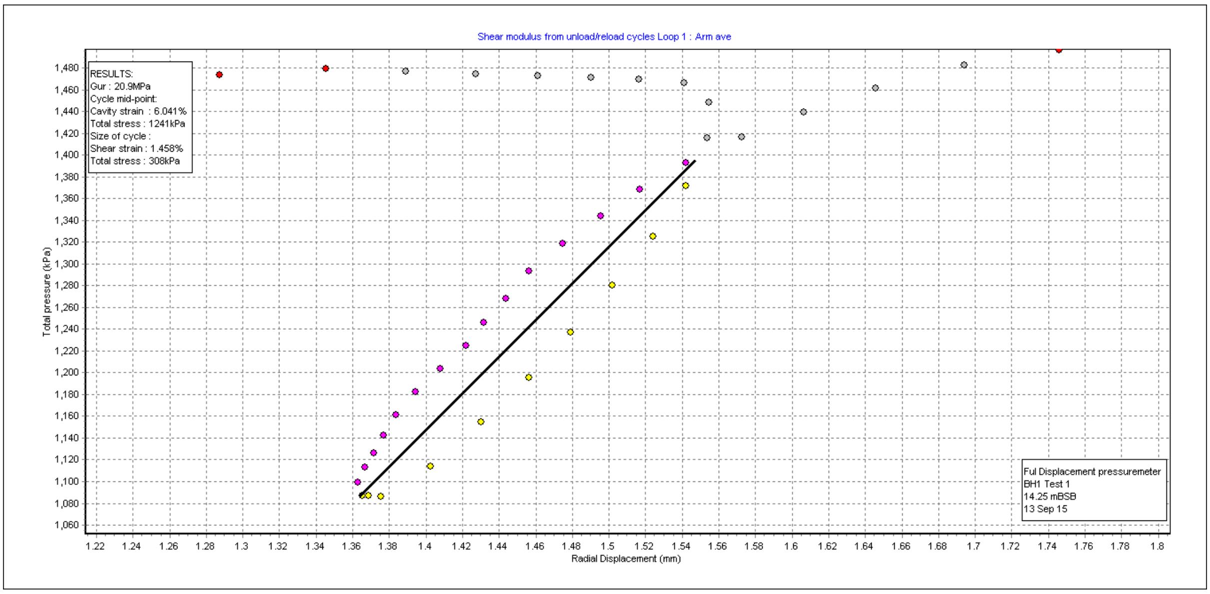


Figure 12.0. Data points as seen on software 'Winsitu'. This graph shows the linear plot of the unload/reload cycles analysed to provide values of shear modulus. NOTE this is undertaken for each unload/reload cycle.

Modulus data is obtained from small cycles of unloading and reloading (as seen analysed in figure 12.0 and 13.0). These give consistent and repeatable descriptions of stiffness characteristics.

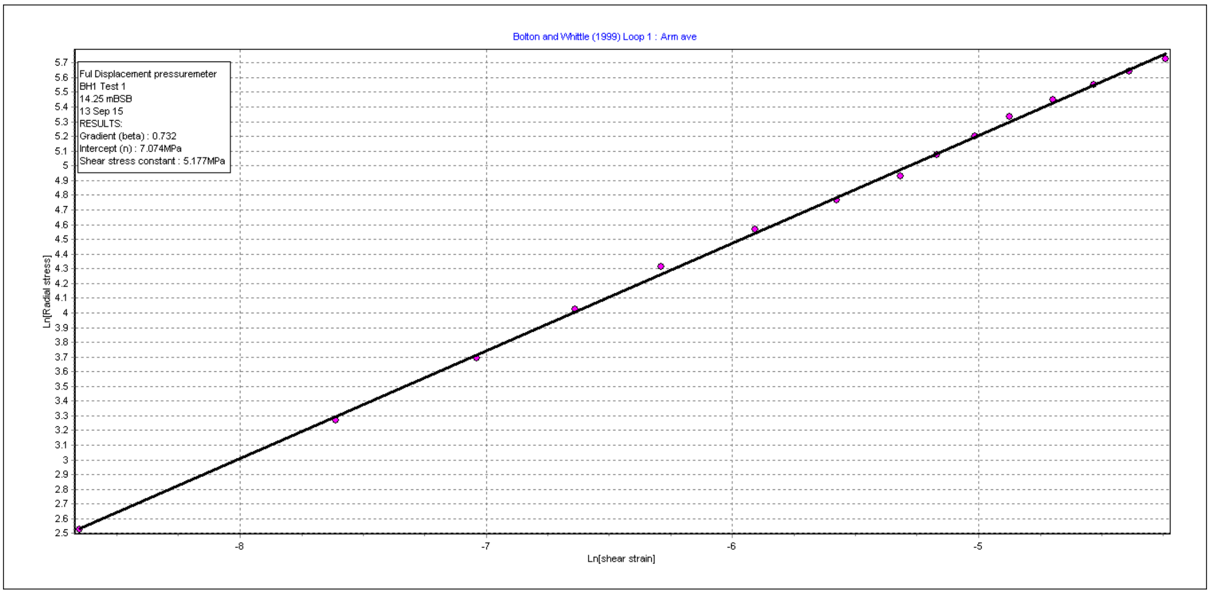


Figure 13.0. Data points as seen on software 'Winsitu'. This graph shows the non-linear plot of the unload/reload cycles. NOTE this is undertaken for each unload/reload cycle.

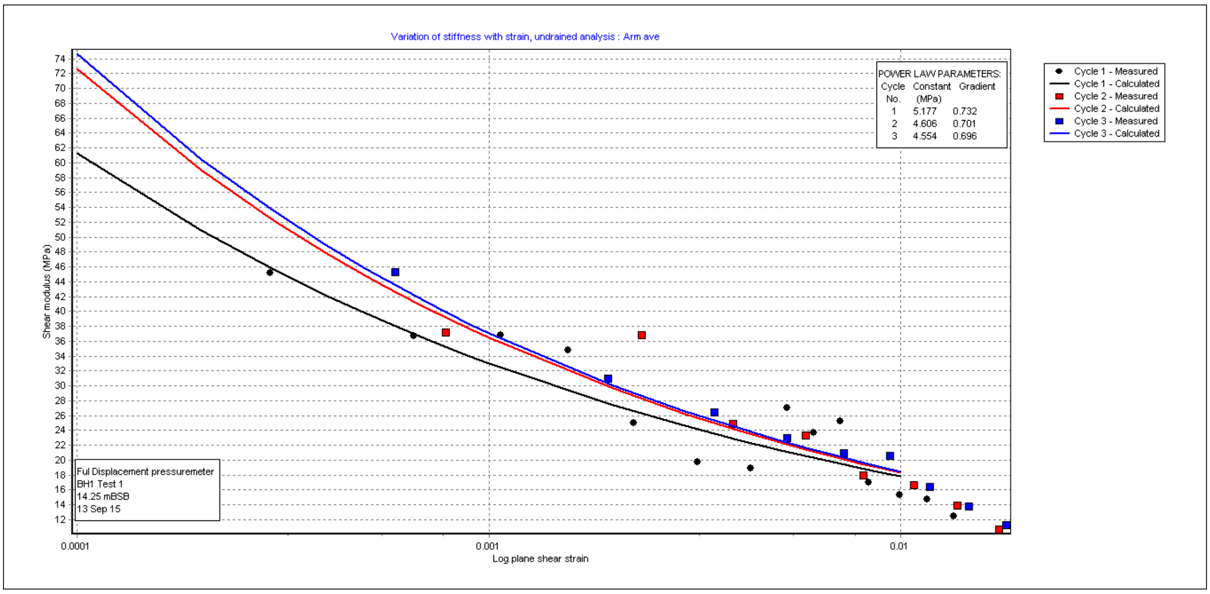


Figure 14.0. Data points as seen on software 'Winsitu". This graph shows the variation of stiffness with strain, undrained analysis.

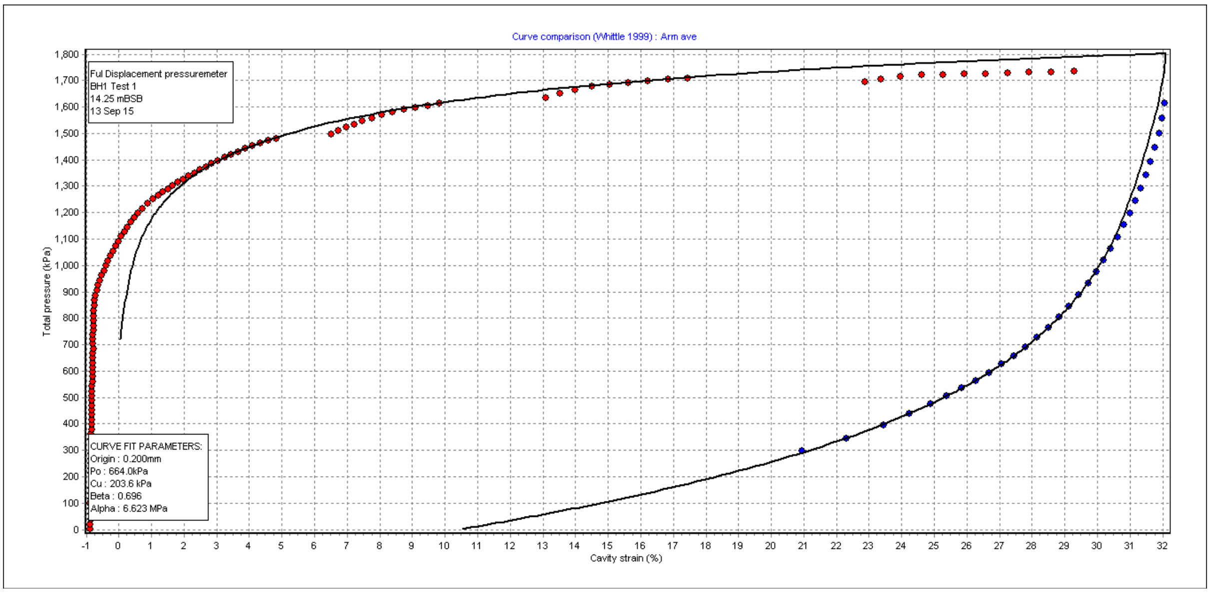


Figure 15.0. Data points as seen on software 'Winsitu'. This graph shows the curve comparison Whittle (1999) analysis for undrained materials.

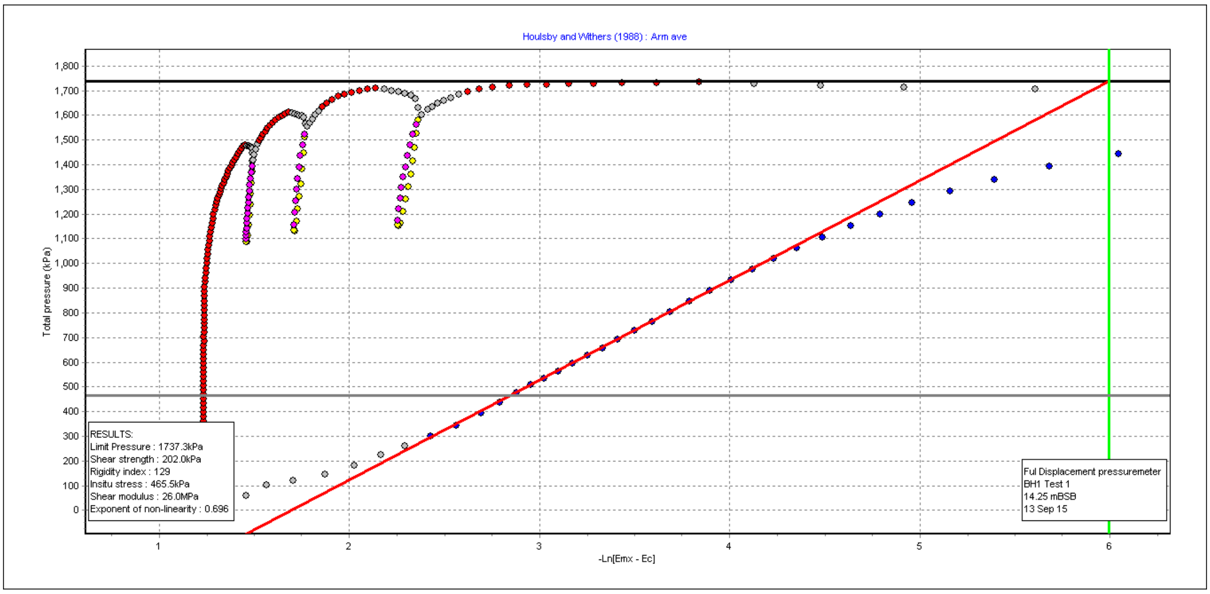


Figure 16.0. Data points as seen on software 'Winsitu'. This graph shows the Houlsby and Withers (1988) analysis.

Tests can been analysed as undrained expansions where the solution proposed by Houlsby & Withers (1987) are used to determine strength, limit pressure, shear modulus at failure and the cavity reference pressure. The analysis assumes a simple elastic:perfectly plastic shear stress:shear strain response from the pressuremeter unloading curve, and that the unloading starts from the material limit pressure.

6.0 Methodology for Operating Air Compressor and Air Cylinder

It is often necessary whilst undertaking Pressuremeter testing to charge/recharge the 12l air cylinder used to supply the compressed air to the probe during testing.

6.1 Equipment

Electric compressor Unit (44kg, Max Pressure 33MPa, 230V/50Hz – power requirements may vary depending on project). 2 x 12l air cylinders (17kg, Max Pressure 30MPa).

Note: Always follow manufacturers instruction manual when operating compressor.

6.1.1 Storage of Compressor and Air Cylinders

Both the air cylinders and compressor must be stored in a cool, dry place. Air cylinders must also be stored, strapped securely into place with a ratchet-strap standing up.

6.2 Charging Operation

6.2.1 Preparation/Pre-operation Checks (Air Compressor)

1. Check compressor for valid PAT test certificate and conduct visual check for damage of wires/cables, pneumatic hoses, plugs, valves, gauges, compressor housing and plastic casing.
2. Check compressor dipstick for sufficient oil level. Top up if required.
3. Check all valves on compressor are shut off completely.
4. Locate suitable location for charge, ensure position is protected from any rainfall or surface water and has a safe/reliable source of electrical power, as well as being away from people eg. away from main gangway/walkway/rest areas (Ask site manager for assistance if necessary).

6.2.2 Setup of Air Compressor

5. Position compressor in chosen location. This should be a two-person lift (compressor weighs 44kg, see Risk Assessment).
6. Connect compressor to Electrical power supply.
7. Ensure physical check that electrical plug connections are sound.

6.2.3 Preparation/Pre-operation Checks (Air Cylinders)

8. Check air cylinder's valve is shut off completely.
9. Check air cylinder has valid in-date inspection certificate and conduct visual check for corrosion/damage to cylinder, valve and rubber protective mesh/base.
10. Position air cylinder in reach of compressor pneumatic hose. Cylinder position must be strapped securely into place with a ratchet-strap standing up.

6.2.4 Charging

11. Connect compressor’s pneumatic hose to air cylinder. Conduct physical check (twisting and pulling motion on pneumatic hose to ensure connection is secure.

    At this point the air cylinder is now ready to be charged following the manufacturer’s instructions.

12. During charging regularly inspect pressure gauge to ensure max pressure of cylinder is not exceeded.

    NOTE: The air cylinders have a max pressure of 30MPa.

6.3 Post-Charging

Once the air cylinder is at the desired pressure as measured by the pressure gauge on the pneumatic hose, the operator needs to safely disconnect the cylinder from the compressor.

5.3.1 Disconnecting Air Cylinder

1. Shut cylinder valve off.
2. Open bleed valve on pneumatic hose (this will bleed the air pressure from the gauge-cylinder section of the hose, thus allowing the hose to be safely unscrewed/disconnected from the air cylinder).
3. Unscrew hose from cylinder.

6.4 Replacing Air Cylinders

When the pressure in a cylinder drops below a usable amount, the air cylinder must be replaced. This does not make the cylinder ‘empty’, and in some cases, there may still be up to 10MPa air pressure in the cylinder. This replacement process requires residual pressure to be bled from the system for it to be safe, and can be completed either mid-test or after/before a test.

6.4.1 Disconnecting Air Cylinder

1. Shut off HPCP valve, thus preventing air flow and pressure from the regulator to the HPCP output/probe. This will maintain the pressure in the probe, but obviously makes it impossible to increase the pressure.

2. The air cylinder valve can now be shut off completely, further isolating the system. This now only leaves the pneumatic hose (between HPCP and air cylinder) and the regulator section of the HPCP being left to bleed to be able to make a safe disconnection.

3. Both the pneumatic hose and the HPCP have bleed valves that can be used to bleed the system. Typically, the HPCP input bleed valve is the preferred option. Open this valve and the pressure in the hose and the regulator section of the HPCP will equalize to atmospheric pressure.

4. The hose can now be unscrewed from the air cylinder. The inadequately filled cylinder can now be refilled (see section 1.0 Methodology for Operating Air Compressor and Air Cylinder).

6.4.2 Connecting a New Air Cylinder

5. Take a full air cylinder and once strapped and secured upright screw the pneumatic hose into the cylinder valve. Ensure all the bleed valves are shut and hose connection is sound.

6. Open cylinder valve, slowly at first to ensure that the air pressure transferring from the bottle to the hose does not escape through a leak caused by an inadequate connection or similar fault. Once the system is secure, open the valve fully. This fully pressurizes the regulator section of the HPCP and the gauge pressure (on the HPCP) should reflect what quantity of pressure is now available to the system.

7. Open the HPCP valve, allowing air flow and pressure to transfer from the regulator to the probe. Continue testing as normal.