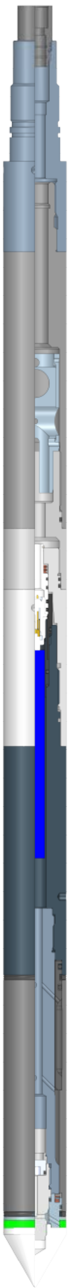
Eijkelkamp GeoPoint
SoilSolutions

Seismic CPT (Geophone version)

User manual



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On these operating instructions

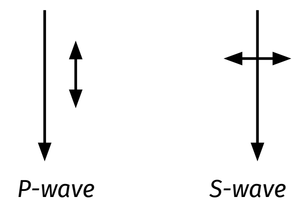
If the text follows a mark (as shown on the left), this means that an important instruction follows.

If the text follows a mark (as shown on the left), this means that an important warning follows relating to danger to the user or damage to the apparatus.The user is always responsible for its own personal protection.

Text **Italic indicated text indicates that the text concerned appears in writing on the display (or must be typed).**

1. Introduction

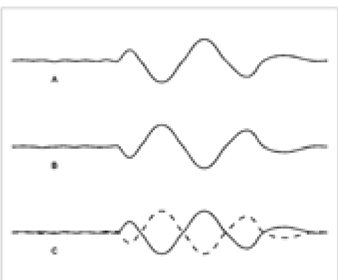
In some cases shear wave velocity studies are required as part of foundation investigations for major structures. Shear wave velocity measurements are an important tool in designing buildings for site specific conditions such as ground-spectral earth quake response. There are two types of waves to distinguish: the compressive waves or so called P-waves and the shear waves, S-waves. In compressive waves, the ground vibrates in the same direction that the waves travels. In shear waves, the ground vibrates transversely to the direction that the wave is propagating.



Shear wave velocity tells us more about the character of the material in-situ. Shear wave velocities are dependent on the shear strength of the material. If you know the velocities of the P and S-waves and the density of the material, you can calculate the elastic properties that relate the magnitude of the strain response to the applied stress.
The elastic properties include:
- Young’s Modulus E
- Shear Modulus G

2. How to measure shear and compression waves

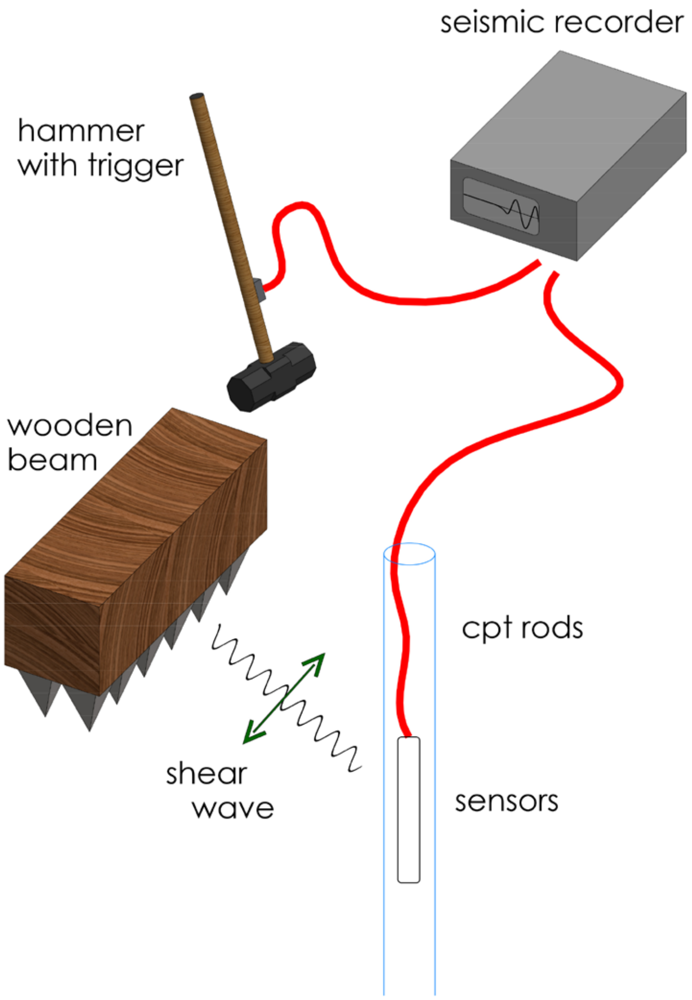
An energy source is needed to generate an elastic wave in the ground and the elastic waves are measured with vibration sensors (geophones). Shear waves are difficult to detect because they travel slower than P-waves. The P-waves arrive first and therefore they can be detected easily. To detect a S-wave it is important to try to generate a “clean” shear wave so no P-waves disturb the signals. The best solution to generate a shear wave is to use a wooden plank weighted down with a vehicle (for example a CPT rig). By hitting the end of the plank with a hammer, a shearing stress is applied to the ground. The geophone will register the first arrival of the vibration followed by larger excursions which die down after a few cycles. To confirm that we really have a shear wave, take another record by hitting the other end of the plank. The registered wave should be in the opposite direction of the previous cycle, see picture below:



3. Field techniques

Cross hole survey is done by drilling 2 holes side by side and put an energy source in one hole and a geophone both on the same depth in the other hole. A so called "down-hole-shear-wave-hammer" is clamped in one hole on a certain depth and generates the shear wave. The geophone connected to a seismograph is lowered in the other bore hole on the same depth and registries the vibration. The procedure is repeated at different depths until a complete set of measurements has been taken. The shear wave velocity for each geological layer is calculated from the distance between the bore holes and the travel time.

Down hole test is done by having the energy source at the surface and the geophones on different depths in the soil. Again a hammer with a horizontal plank can be used as energy source to generate the shear wave. The wooden beam must be put on the ground by applying weight on top of the beam. You can use the CPT rig as ballast. The geophones are to be lowered in a bore hole. The geophones are connected to the seismograph as well as the trigger switch. The trigger switch is mounted near the head of the hammer with the help of tie-raps or tape. The figure below shows the complete setup:



The advantage of the down hole survey is the fact that you only need one hole.

4. Seismic CPT

Seismic CPT is similar to the down hole survey but instead of making a bore hole, the geophones are pushed in to the soil directly with a CPT rig. With the help of the CPT technique, the geophones are pushed in the soil rather quickly and cost effective.

The seismic CPT cone is based on 2 main parts, a standard CPT(u) cone for measuring cone resistance, local friction, inclination and optionally the pore pressure and the seismic adaptor with 3 geophones for measuring vibrations in X, Y and Z orientation. Optionally it is possible to mount a second seismic adaptor with a set of 3 geophones on a distance of 500 or 1000 mm above the first seismic adaptor. With a combination of two seismic adaptors you have the possibility to determine the velocity locally by calculating the time difference between the signals of the two seismic adaptors.

With seismic CPT, the seismic test and the CPT test can be done at the same time. Starting with the CPT test once a certain depth has been reached the CPT test can be stopped to do the seismic down hole test and after this seismic test is done, the CPT test can be continued without any problem. All data are brought to the surface with one cable. A splitter box simply splits the data of the geophones to the seismograph and the data of the CPT cone to the CPT data logger (Geologger).

For the performance of seismic CPT tests the following equipment is required:
- Data acquisition system (Geologger)
- Depth synchronizationsystem
- Electric cone (or piezocone)
- CPT sounding tubes
- Automatic push-and-pullclamp
- PC-based computers
- Data acquisition software
- CPT sounding cables
- Seismic module with 3 geophones
- Signal splitter box
- Seismograph(Geode ES-3000)
- Hammer with hammer trigger switch


Datalogger


Depth synchronization


Cone


CPT tubes


Computer


Push and pull clamp


CPT cable


Seismograph

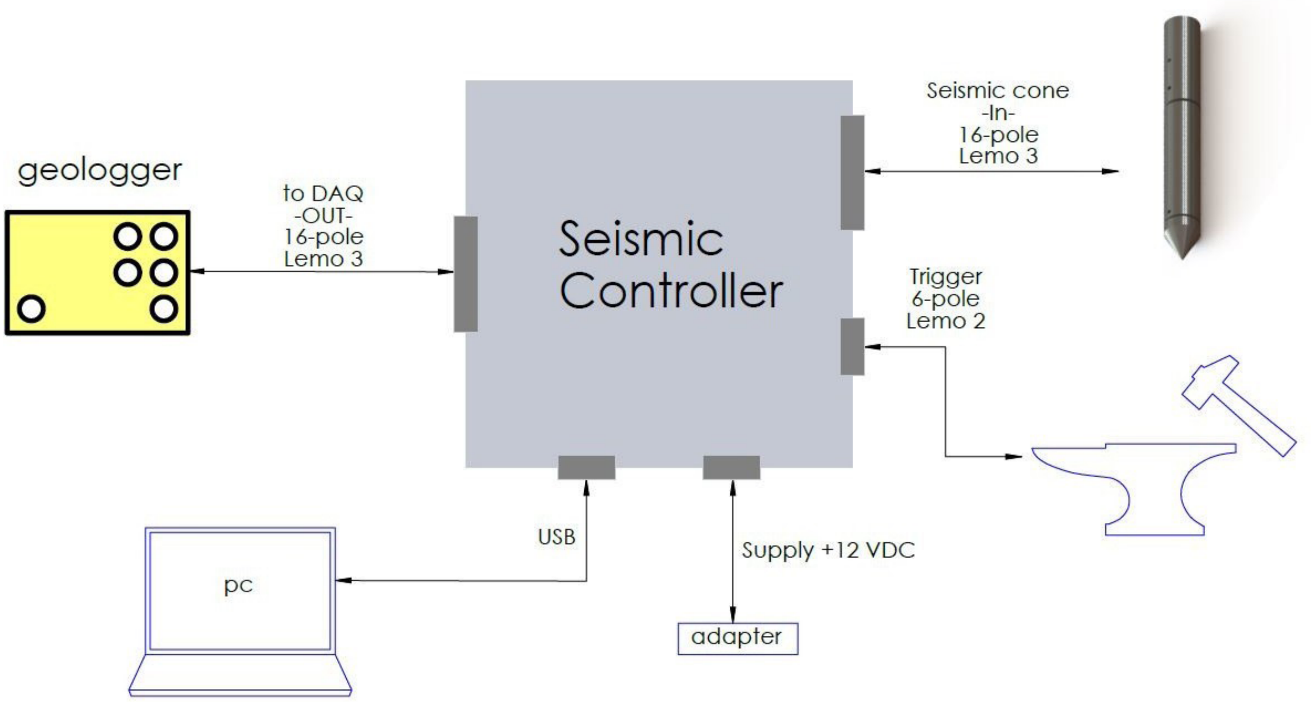

Seismic adapter


Hammer


Software

Please consider the following guidelines on how to do seismic CPT testing. This description is limited to the seismic survey aspects. The CPT test is described in the manual "Electrical CPT Testing with Standard Cone or Piezocone"

In fact two different systems are merged to be able to do two test simultaneously. The seismic adaptor is attached on top of the electric CPT cone and all signals come together in one CPT sounding cable. On the surface the signals of the seismic adapter and the electric CPT cone are separated again by a splitter box to bring the right signals to the right data logger: the seismic signals are directed to the seismograph and the CPT signals are directed to the Geologger. The seismograph is connected to the Ethernet port of a computer and the Geologger is connected to the RS232 or USB port of another computer. Some computers are able to deal with both signals at the same time, but it is recommended to do the seismic tests with two computers for more stable data processing.



For further connections of the Geologger and the depth registration system etc. we refer to the manual "Connecting Diagram Electrical CPT Equipment"

5. Working procedure of the field test

1. Connect all cable as mentioned above.
2. Make all preparations for the CPT according the manual “Electrical CPT Testing with Standard Cone or Piezocone”.
3. Prepare the seismograph and the seismic software.
4. Place the wooden plank or the anvil underneath a solid support like one of the leveling jacks or the crawler as close as possible to the CPT hole.
5. Put the seismic adapter with the cone in the CPT penetrometer push in the right orientation (X or Y longitudinal to the hammer impact direction.
6. Start the CPT test according the CPT manual.
7. Pause the CPT test on the level where the first seismic test has to be done.
8. Release the push and pull clamp or the pushing head of the CPT penetrometer pusher to prevent any direct vibration from the anvil through the CPT rig to the CPT tubes. That could disturb the wave measurements by direct vibrations of the CPT tubes to the seismic adaptor.
9. Run the seismograph and the seismic software.
10. Hit the hammer with sufficient energy horizontally to the plank or anvil with the trigger switch attached.
11. Convince yourself that the trigger switch has activated the recording. If necessary adjust the sensitivity of the trigger switch.
12. Repeat the impact hits according the selected amount of “stacks”. The signals are “stacked” to get a better signal/noise ratio.
13. If required, (it is recommended) do a second test in the opposite direction by hitting the plank from the other side. By comparing the 2 results you can prove that the wave is indeed a shear wave by checking that the S-wave is in reverse direction to the previous test. If not, the recorded wave is not a S-wave but a P-wave.
14. If required do a P-wave test by hitting the hammer vertically on top of the plank or anvil.
15. Continue the CPT test to the depth of the next seismic test. (Usually 0,5 or 1 meter lower)
16. Repeat procedure 8 – 13 again to do an additional seismic test.
17. Continue with the CPT and seismic depth until the required depth has been reached.

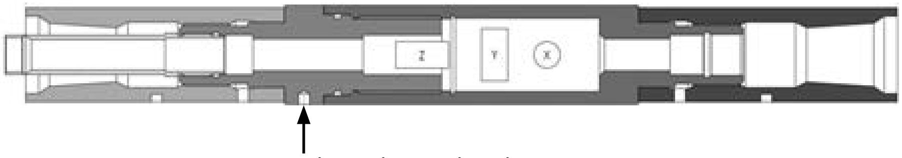
☞ **For down-hole surveys, start with the geophones near the top of the hole and take three separate records, one on each end of the plank (S-waves) and one vertical to get the P-wave. Look at the records and see if they are reasonable, shear waves that reverse and a P-wave that arrives in about half the time with higher frequencies. Next push the seismic adapter to a lower depth and repeat the procedure. After doing some tests on different depths, convince yourself that the results look reasonable to what you should expect. Longer travel times at lower depths, reverse amplitudes on opposite hammer hits, quicker arrival on the P-wave.**

☞ **By stacking the hits on each depth, you can clean up your records. Repeating the same hits will give a better signal/noise ratio. Be aware that in that case you should hit the hammer only on one end of the plank otherwise the reverse hits will decrease the signals because of the reverse signals.**

☞ **The depth interval at which the seismic tests must be done is depending on site conditions. Closer intervals will result in a better resolution and more accurate velocities but will require more survey time. A normal interval between the tests is appr. 0,5 or 1 m.**

☞ **The first arrival times are difficult to determine once the seismic adapter is on a lower depth. To get more precise time interval measurements, it is common to pick the first large peak in the wavelet.**

Orientation:
In the seismic adaptor two horizontal geophones are mounted (X and Y direction) and one geophone for the vertical P-waves (Z-axis). Better surveys and data do result if one of the geophones is continuously aligned with the plank. The orientation can be seen by the mark on the seismic adapter, see picture below. The mark is a notch in the thicker part of the seismic adapter and this is the orientation of the Y-sensor direction.



Notch for orientation Y-direction

6. Technical specifications seismic adaptor

Item	Specification
Length	380 mm
Diameter	44 mm
Measuring orientation	X, Y and Z axis
Geophone	3x Geospace GS-14-L3
Sensitivity	290 mV/ips (± 15%)
Natural frequency	28 Hz (± 20%)
Coil resistance	570 Ohm (± 5%)
Coil inductance	45 mh
Damping factor	0.18 (± 30%)
Damping constant	172
Displacement limit	2.29 mm (0.09 in)
Inertial mass	2.155 gr (0.076 oz)
Orientation angle	± 180°
Operating temperature	-45°...+100°C
Storage temperature	5°...+40°C
Shock resistance	5000 G

7. Technical specifications seismograph

Item	Specification
A/D Conversion	24 bit
Dynamic range	144 dB (system), 110 dB (instantaneous, measured) at 2 ms, 24 dB
Distortion	0.0005% @ 2 ms, 1.75 to 208 Hz
Bandwidth	1.75 Hz to 20 kHz (low corner frequency option available)
Common mode rejection	> -100 dB at <=100 Hz, 36 dB
Crosstalk	-125 dB at 23.5 Hz, 24 dB, 2 ms
Noise floor	0.2 uV, RFI at 2 ms, 36 dB, 1.75 to 208 Hz
Stacking trigger accuracy	1/32 of sample interval
Maximum input signal	2.8 VPP
Input impedance	20 kOhm, 0.02 uf
Preamplifier gains	Software enables selectable gain pair of either 24 or 36 dB
Anti-alias filters	-3 dB at 83% of Nyquist frequency, down 90 dB
Pre-trigger data	Up to 4,096 Samples. Optional event detection software enables system for earthquake, vibration monitoring
Sample interval	0.02, 0.3125, 0.0625, 0.125, 0.25, 0.5, 1.0, 2.0, 4.0, 8.0, 16.0 ms
Record length	16,000 samples standard (64,000 samples optional)
Delay	0 to 9999 ms in 1 ms steps
Data transmission	Ethernet protocol
Auxiliary channels	All channels can be programmed as either AUX or DATA
Instrument tests	Optional built-in daily, weekly and monthly testing available External laboratory quality oscillator available to measure noise, crosstalk, dynamic range, gain similarity and trigger accuracy to factory specification
Acquisition and display filters	Low Cut: OUT, 10, 15, 25, 35, 50, 70, 100, 140, 200, 280, 400 Hz, 24 or 48 dB/octave, Butterworth Notch: 50, 60, 150, 180 Hz and OUT, with the 50 dB rejection bandwidth 2% of center frequency High Cut: OUT, 250, 500 or 1000 Hz, 24 or 48 dB/octave
Line testing	Real time noise monitor displays real-time output from geophones
Data storage	Stores data locally on the hard-disk of the computer for transfer to portable media
Triggering	Positive, negative or contact closure. Threshold is adjustable by means of software
Data formats	SEG-2 standard. SEG-D and SEG-Y available on request
Power supply	12 Vdc
Power consumption	0.65 W /channel during acquisition
Plotters	Drives a variety of NT compatible printers including Printrex 4, 8 and 12 inch plotters
Operating and storage temperature	-30°...+75°C
Ingress protection	Waterproof and submersible
Shock resistance	Withstands a 1 m drop onto concrete on 6 sides and 8 corners
Operating system	Windows 7, 8 and 10