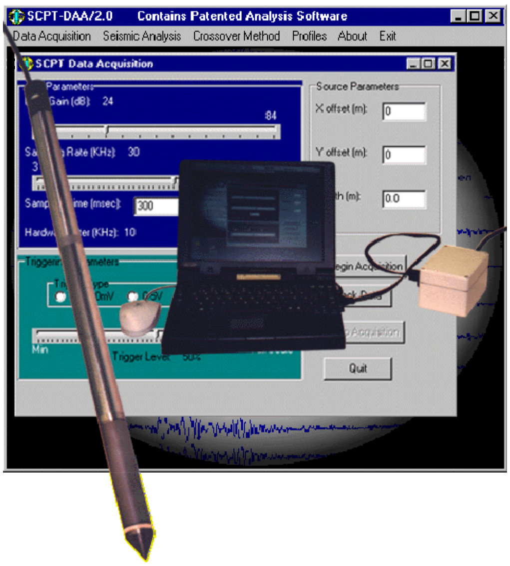
Seismic CPT



Seismic Cone Penetration Testing (SCPT) has proven to be a very valuable geotechnical tool in facilitating the determination of low strain in-situ compression (P) and shear (S) wave velocities. The P-wave and S-waves velocities are directly related to the soil elastic constants of Poisson's ratio, shear modulus, bulk modulus and Young's modulus. The accurate determination of P-wave and S-wave arrival times from the recorded time series is of paramount importance to the evaluation of reliable seismic wave velocities.

The seismic CPT acquisition is conducted with a seismic adapter, attached to a 10cm^2 or 15cm^2 subtraction or compression CPT(U) cone. The adapter is designed such that the seismic sensors record the soil profile's response to low strain seismic disturbances.

In SCPT testing there are typically two types of sensors used, velocity (i.e. geophones) and acceleration (i.e. accelerometers).

A seismic sensor can be satisfactorily modelled as a linear second order system, with a characteristic natural frequency and damping factor, which transforms the sensor input of body waves and associated random noise propagating through the earth into an electrical signal.

For a good definition of the frequency spectrum of the recorded signal, i.e. to avoid smearing, the GeoMil seismic adapter is equipped with accelerometers (1 Hz - 10 kHz) and not with geophones (typically 10 - 300 Hz).

To simplify the data acquisition, all hardware and software components are designed to run with a notebook computer connected to a "Signal Conditioning System", rather than the traditional seismograph. For quality assessment and proper data analysis, the frequency filtering of data is done after acquisition and not during the recording. The measured values are transferred as voltage signals by means of a cable connected on surface to the "Signal Conditioning System" where CPT data is separated from the seismic data.

The CPT data are classically logged by the GME acquisition unit and further processed by the acquisition software CPTest© running on a computer with a *Microsoft Windows* 32bit operating system.

The signal conditioned seismic data is A/D converted by a PCMCIA card and then processed by SC(1-15)-DAC™ software from Baziw Consulting Engineers (BCE). The SCPT systems can be expanded up to 15 channels (30 channels if two A/D boards are used), but typically uniaxial (SC1-DAC), biaxial (SC2-DAC), triaxial (SC3-DAA), and true interval six channel systems (SC6-DAA) are used.

In general terms, the seismic cone is advanced to the depth of interest using a hydraulic reactionary pushing force like generated with the GeoMil static penetrometers.

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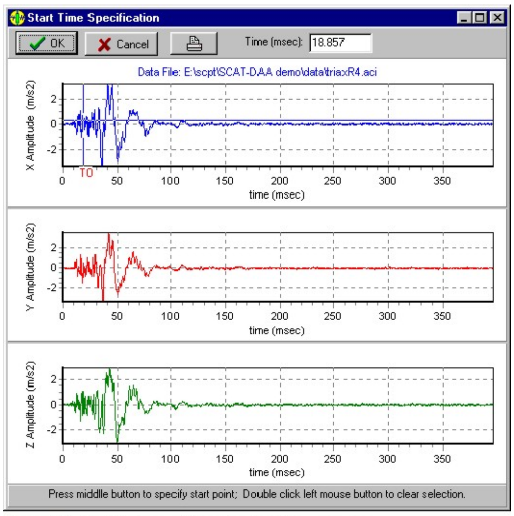
An important factor in SCPT is to generate clean, strong and reproducible source wavelets. The particle motion of the P-wave is in the direction of the ray path while the particle motion of the S-wave is perpendicular to the ray path. The S-wave can be polarised both parallel (SH) and perpendicular (SV) to the ground surface. When a P or SV wave strikes a boundary both SV and P-waves are generated. A SH wave will only generate SH-waves at boundaries and therefore simplifies shear wave seismic analysis.

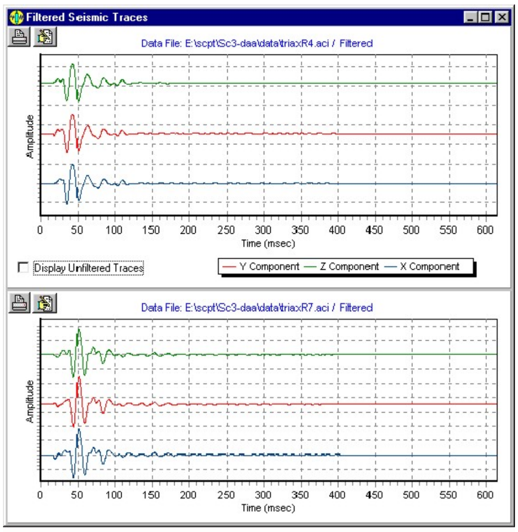


Seismic sources are designed to generate either dominant P- and SV-waves (e.g. Buffalo gun fired in the ground) or dominant SH waves (e.g. hammer beam). The hammer beam comprises of applying a hammer blow laterally to the sides of special designed plates fixed to the penetrometer. The hammer beam generates excellent polarised SH wavelets and it is standard applied in reverse polarity analysis (Baziw, 1988) .

BCE provides both the SC(1-15)-DAC™ data acquisition and the SC(1-15)-RAV™ data reduction, analysis and visualisation software packages. SC(1-15)-RAV™ implements patented (i.e., US Patent #5,177,709 and Canadian Patent #2,077,387) DSP software in deriving seismic velocities and attenuation Q values from SCPT data.

From the recorded time series, arrival times for the S-waves and P-waves are determined and corresponding velocity profiles derived. The accurate arrival time estimates are critical so that the investigator is confident in the derived velocity estimates.

P-wave and S-wave incremental velocity determination is directly dependent upon the quality of the recorded seismic time series and the ability to extract the desired wavelets (i.e., P or S) understudy. The seismic P and S body waves and ambient background and electrical noise constitute the recorded seismic time series. The ability to spectrally identify and digitally isolate the desired wavelets requires fast response and high bandwidth sensors. Slow response and low bandwidth seismic sensors may result in unrecoverable distortions in the recorded time series.



Accurate in-situ P-wave and S-wave velocity profiles are essential in geotechnical foundation designs. These parameters are used in both Static and Dynamic Soil Analysis where the elastic constants are input variables into the models defining the different states of deformations such as elastic, elasto-plastic, and failure (Finn, 1984).

Another important use of estimated shear wave velocities in geotechnical design is in the liquefaction assessment of soils. Since the shear wave velocity is influenced by many of the variables that influence liquefaction (ge., void ratio, soil density, confining stress, stress history, and geologic age), it is an excellent index of liquefaction.

The seismic cone has proven to be a very accurate and reliable tool in the determination of Vs and Vp profiles. The many advantages of the seismic cone consists of excellent soil probe coupling, a controllable source, and cost effectiveness because it is a retrievable probe. Details of the seismic cone, the downhole test procedures, and comparisons with the crosshole results at several sites have been described by Campanella et al (1986).

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