The CSWS provides:

- ***Automated, computer-controlled test procedures*** ✓
- ***Easy-to-use, MS Windows®-based user interface*** ✓
- **Cost-effective compared with alternative methods** ✓
- ***Easy to use:*** ✓
  - ***set up in 5 minutes***
  - ***portable equipment***
  - ***non-invasive testing***
- ***Stiffness v depth available immediately in field*** ✓
- ***Time domain output*** ✓
- ***On-line Fast Fourier Transform (FFT)*** ✓

Continuous Surface Wave System (CSWS)

What is it?

The Continuous Surface Wave System (CSWS) enables a shear stiffness-depth profile to be determined to depths between 10m (in clays) and 30m (in some granular soils and weak rocks) without the need to provide a borehole. It provides on-line data processing such that the stiffness-depth profile may be viewed as the test is in progress. This allows the operator to assess the quality of the data before moving to another location. These profiles enable geotechnical engineering predictions of surface settlement.

Recent developments in laboratory small strain stiffness measurements and the use of non-linear finite element analysis have closed the (perceived) gap between static and dynamic measurements of stiffness. Thus, stiffness parameters, determined from seismic velocity measurements, can be used in geotechnical design. Traditionally, geophysics has been used only as an indirect means of targeting and dimensioning sub-surface features. This application has its origins in oil and mineral exploration.

The CSWS is set up on the ground surface and propagates Rayleigh waves which are constrained within a zone which is, approximately, one wavelength in depth. In ground where the stiffness changes with depth, these elastic waves are dispersive in nature, which means that they travel at a velocity which is dependent upon frequency and wavelength.

The CSWS uses a frequency controlled vibrator to regulate the frequency of these surface waves, thus permitting a dispersion curve (velocity against frequency or wavelength) to be readily determined (see Fig. 1). By using the theory of elasticity, shear wave velocity and shear modulus G can be determined from these velocity measurements.

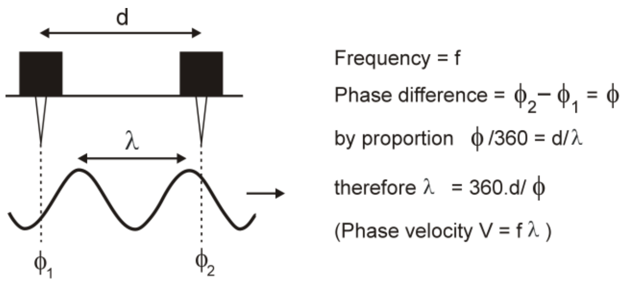

Fig. 1 By knowing the frequency, f, and the change in phase with distance from the vibrator, the phase velocity of the ground Rayleigh waves can be determined

Technical specification

- **Resolution of measurement**: 16 bit data capture
- **Frequency of measurement**: up to 225,000 samples per second
- **Connection:** USB connection to users laptop for control and acquisition
- **Sensor number:** Standard system for 2-6 geophones, upgradeable to a maximum of 12
- **Sampling type:** Each channel sampled simultaneously (*New feature for version III)*
- **Size of control unit**: 400mm x 380mm x 150mm (Nominal size including outer padded bag|)
- **Weight of control unit**: 5.5kg (approximate weight)
- **Power**: 12-24V DC (Runs continually for up to 8 hours with user supplied 12V battery)
- **Padded transport case**: with built in laptop weather hood
- **Size of ground vibrator**: 450mm x 350mm x 180mm
- **Weight of ground vibrator**: 70kg (489N force)
- **Integral geophone amplification and signal conditioning**
- **Can be used as a Spectral Analysis of Surface Waves (SASW) test system using an impact source**

GDS Instruments• Tel: +44 (0) 1256 382450 • Fax: +44 (0) 1256 382451 • e: info@gdsinstruments.com • web: www.gdsinstruments.com

System set-up

The set-up is shown in Figs 2 and 3. A computer-controlled inertial vibrator applies a precisely regulated and measured continuous vertically polarized disturbance to the ground surface. This generates surface waves which are detected by a line of sensors (geophones) which are co-linear with the vibrator. The signals from the sensors are fed back to the computer which analyses the phase relationships between them and so computes the velocity of the surface wave. By changing the frequency of the continuous wave generated by the vibrator, velocity measurements can be made over a range of depths. The measured dispersion curve is inverted to produce a profile of surface wave velocity with depth. By entering the bulk density and its Poisson's ratio of the soil/rock, this profile is converted to that of shear modulus with depth. These parameters may be estimated on site with minimal errors in stiffness.

The plot of shear stiffness against depth may be viewed after each stiffness measurement is made. Typically a shear stiffness-depth profile will contain between 50 and 100 separate stiffness measurements at different depths. By using smaller frequency increments, even more stiffness measurements may be made. A typical profile will take about 45 minutes to produce. If the cost of each individual stiffness measurement is considered, the surface wave system works out cheaper than other direct methods of measurement such as the pressuremeter and the plate loading test.

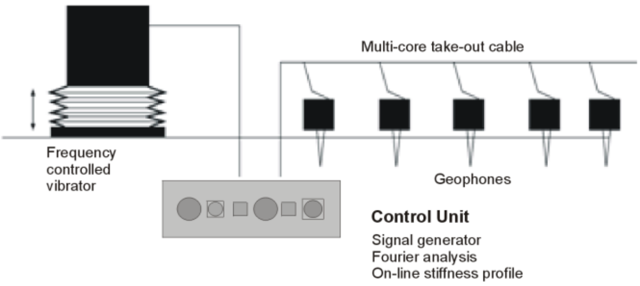

Fig 2. Diagrammatic layout of the CSWS

Fig 3. Photograph showing a six-geophone layout on one of our test sites

System features (* denotes new for version III)

- Provides on-line shear modulus with depth profile to depths of up to 30m depending on the type of soil or weak rock
- Enables rapid assessment of ground variability across a site in terms of stiffness
- Provides stiffness parameters for ground that is difficult or impossible to sample in a representative manner, e.g. granular soils and highly fractured rock
- Provides between 50 and 100 (or more) stiffness measurements per location
- Can be operated by two people in the field
- Enables predictions of settlement
- Verifies soil improvement, e.g. from dynamic compaction, vibrofloatation and classic consolidation
- Enables the measurement of Gmax which can provide a valuable benchmark for stiffness investigations in soils
- Simultaneous sampling of all channels*
- Rugged, robust, smaller and lighter (version III weighs only 5.5kg)*
- Greater power efficiency (smaller battery needed)*

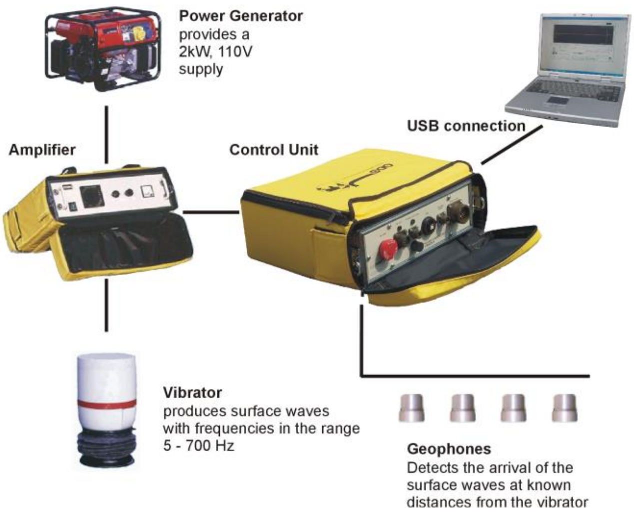

Fig 4. Principal Components of CSWS

Why buy CSWS?

- Automated test software - the user enters the required test frequencies and the software runs the complete test automatically.
- User friendly, easy-to-use software interface.
- Flexible data output which can be imported directly into Microsoft® Excel.
- Data output includes time domain, frequency domain (magnitude and phase), coherence and stiffness v depth using the Lambda/3 method.
- Can be used as a Spectral Analysis of Surface Waves (SASW) test system using an impact source

Due to continued development, specifications may change without notice.