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GDS INSTRUMENTS LIMITED

World Leaders in Computer Controlled Testing Systems for Geotechnical Engineers and Geologists

Hardware

Continuous Surface Wave System

Test Specifications

1. Introduction

The continuous surface wave method (CSW) employs a frequency controlled vibrator and geophones. The vibrator generates a Rayleigh wave (surface wave) in which the ground motion becomes insignificant below a depth of one wavelength. By varying the frequency of the vibrator Rayleigh waves with different wavelengths can be produced thereby penetrating the ground to different depths. The characteristic velocity of these waves can be determined by measuring the signals received at the geophones. The data collected can be processed to produce values of maximum shear modulus at different depths. The method has been found to give reliable data to depths of 10m in chalk although the maximum depth of penetration is between 20m and 30m (Matthews, 1993).

2. Equipment

The equipment required for CSW surveys comprises the following components:

1. Frequency controlled vibrator. Produces surface waves with frequencies in the range 5 Hz to 800 Hz.
2. Geophones (6) - Vertical motion velocity transducers with natural frequencies of either 2 Hz or 4.5 Hz.
3. Control unit - Synchronises data acquisition from the geophones and provides the control signals for the vibrator.
4. Drive unit for the vibrator - Amplifies the control signal to drive the vibrator.
5. Laptop PC - Allows the operator to set the frequencies sent to the vibrator and processes the data from the geophones to produce a stiffness depth profile on site.
6. Power generator - Provides 2 kW 110 v supply.

3. Field Procedure

The surface wave technique which will be employed is the continuous surface wave (CSW) method.

The ground surface at each location will be prepared by removing the surface vegetation (0.05 m2 approx.) and soil to a depth of about 150 mm in order to create a flat surface on which to place the vibrator. The energy source (an electro-mechanical vibrator) is placed on the prepared ground surface. A row of between two and six geophones is placed on a line which is co-linear with the vibrator. The vibrator is energised using the controller and drive unit at a known frequency within the band 5 to 200 Hz approximately. The range of frequencies and the frequency increment are set by the operator using a laptop PC connected to the control unit. The generator is positioned at least 30 m away from the vibrator on a line which is perpendicular to that of the line of the geophones.

The signals received at the geophones are recorded digitally in the time domain (i.e. ground movement v. time) by the control unit and subjected to Fourier transform in order to convert the signals into the frequency domain (i.e. spectral amplitude v. frequency). The frequency domain data are used to determine the phase of the signal generated by the vibrator at each geophone location. The phase information is used to calculate the wavelength of the mono frequency Rayleigh wave. The phase velocity of this Rayleigh wave is determined from this wavelength and frequency.

The procedure outlined above shall be repeated for a number of different frequencies until sufficient measurements have been taken to define the modulus depth profile to the maximum depth possible for the existing ground conditions.

Preliminary stiffness depth profiles shall be viewed on site. The maximum shear moduli will be determined from the measured Rayleigh wave velocities using elastic theory as outlined in Matthews et al. (1996). A Poisson's ration of 0.25 will be employed and an average bulk density based on values obtained from the nearest boreholes. The depth assigned to each stiffness measurement will be derived using the factored wavelength method of inverting the dispersion curve (Rayleigh wave velocity v. wavelength) described in Matthews et al. (1996). A factor of 3 will be used to determine the depth (i.e. z = wavelength/3) unless there is evidence suggesting that the increase of stiffness with depth is very small in which case a factor of 2 will be used.

It has been shown that simple inversion techniques such as the wavelength/depth method cannot correctly recover the stiffness depth profile when there are rapid changes of stiffness with depth (Clayton et al., 1995). In such cases interpretation of the dispersion curve using iterative forward modelling based on dynamic finite element predictions of surface motion is necessary to obtain an accurate stiffness profile (this approach is not currently available with the GDS system software).

Once the vibrator and geophones have been positioned the following data shall be entered into the computer:

1. Bulk density of the soil.
2. Poisson's ratio - This is normally estimated. The error in G resulting from a gross error in Poisson's ratio is less than 10%.
3. The distance from each geophone to the centre of the vibrator.

The computer then performs a surface wave test using the frequency range 5 to 100 Hz with an increment of 5 Hz. A graph of maximum shear modulus against depth (using wavelength/3) is plotted on the screen as the test proceeds. At the end of the test the operator may choose to set a series of smaller frequency ranges with different frequency increments if there are gaps in the stiffness profile that require more data. Once the operator is satisfied with the data it shall be stored on disk. The minimum number of stiffness measurements is 20.

The data shall be prepared in a digital form with a short report describing the test method and assessing data quality.