Evaluation and Analysis of Sandy Subgrade Stiffness of Transportation Systems by Continuous Surface Waves and Plate Loading Tests

A. Haddad, Associate Professor , Department of Civil Engineering, Semnan University, Semnan, Iran
Gh. Shafabakh, Associate Professor, Department of Civil Engineering, Semnan University ,Semnan, Iran
E-mail: ahadad@semnan.ac.ir

ABSTRACT

New demands in societies for development of transportation networks such as highways, railroads, airports, bridges and tunnels, has caused the classic methods of subsurface and sub-base stiffness evaluating to be substituted with the advanced characterization methods rapidly. At present most methods for of stiffness parameters evaluation are based on field tests or laboratory tests on undisturbed samples in laboratories. The results of these tests are often affected by disturbance of samples and insertion effects. Values of stiffness estimated in this way can be expected to be far superior to many techniques used routinely today. For example, oedometer testing (a one-dimensional compression test), external strain triaxial testing, and penetration testing, where poor performance in predicting stiffness has been known for decades. Continuous Surface waves (CSW) method may be used to determine shear stiffness in soil or rock layers in subgrade of transportation systems. In this paper the continuous surface waves system, being used to determine stiffness parameters, is firstly introduced and then the results of field stiffness measurements carried out on a sandy sub-grade at the south of Iran (Maroon) are presented. The Continuous Surface Wave used in this testing is completely personal computer based and controlled. The surface wave source used is an electromagnetic vibrator capable of exerting a peak sine force of 498N, Fig 1.

Figure 1: Continuous Surface Wave System being used on a sandy subgrade at the south of Iran (Maroon).

The surface waves generated are detected by low natural frequency (2Hz) geophones, the outputs of which are passed through signal conditioning amplifiers and then to a high speed 16-bit data acquisition unit. To acquire data the vibrator is placed on a level ground surface and a row of between three and six 2Hz geophones is inserted co-linearly with it. The vibrator is energized at discrete frequencies between 5 and 600 Hz at operator specified intervals. The signals received at the geophones are recorded digitally in the time domain and subjected to a Fast Fourier Transform to convert the signals into the frequency domain (i.e. spectral amplitude v. frequency). The frequency domain data is used to determine the phase of the generated signal at each geophone location. The geophones are positioned at known distances apart, d, and so the phase difference between the geophones, φ, can be used to calculate the wavelength, λ, for each discrete Rayleigh wave frequency as Eq.1:

$$\lambda = \frac{2\pi d}{\phi} = \frac{2\pi d}{\phi_2 - \phi_1} \quad (1)$$

The phase velocity of the Rayleigh wave, V_R, is determined from the wavelength and the frequency, f as Eq.2:

$$V_R = f \times \lambda \quad (2)$$

The noninvasive nature of this method is especially advantageous when testing environmentally sensitive materials, such as cohesion less soils or sandy subgrades. In this study the stiffness parameter (G_0) is correlated with some physical sub grade properties like void ratio and confinement pressure based on Stokoe's Eqs. 3 and 4. Fig.2. shows the correlation between CSW test results and Eqs 3 and 4 at the relevant site.

$$G_0 = 6.104 \cdot \frac{(2.97 - e)^2}{1 + e} \cdot (\sigma'_0)^{0.5} \quad (3)$$

$$G_0 = 15.73 \cdot \frac{(2.17 - e)^2}{1 + e} \cdot (\sigma'_0)^{0.4} \quad (4)$$

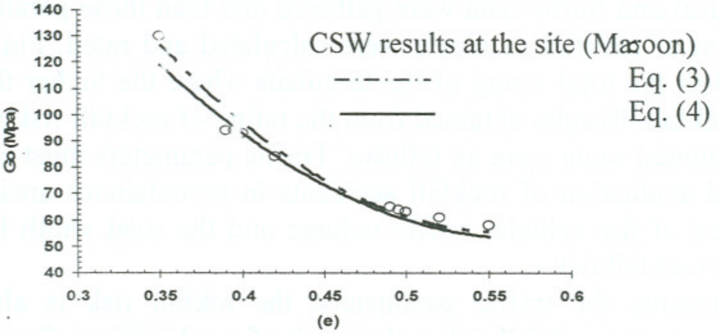

Figure 2: Comparison of stiffness from CSW test results and Stokoe's Eqs 3 and 4 at the relevant site

Moreover the sub-grade stiffness degradation curve with loading is evaluated by combination of continuous surface waves test results and a series of plate loading tests at the same points.

Keywords: Subgrade stiffness, continuous surface wave, maximum shear modulus