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Determination of Sandy Subsoil Stiffness on the Basis of Surface Vibration Measurement

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Abstract

The main aim of the study is an attempt of determination of the stiffness modulus of sandy subsoil based on analysis of data recorded during the measurements of vibrations conducted on the surface of the ground. The procedure proposed in the article is similar, to some extent, to the method of Spectral Analysis of Surface Waves (SASW). The main difference between the proposed way and the SASW method is application of a different type of a ground load, the use of accelerometers instead of geophones and application an backward analysis in place of the most frequently used in geophysics factored wavelength method. Field tests of acceleration of vibrations were carried out at measuring points located at a distance of 5 m and 10 m from the source of vibration. The Light Falling Weight Deflectometer (LFWD) was the source of vibration. Measurements of vibration were executed using measuring system produced by Siemens (LMS Scadas Recorder). The determination of the subsoil stiffness was made on the basis of obtained results in two ways. The first simple way was based on measuring the time of movement of the Rayleigh wave between the measuring points. The second way was to use the own author's computational program and backward analysis. The program based on the Finite Difference Method (FDM) enabled the description of wave propagation in the ground under the impact load. The proposed method allowed the determination of the average values of stiffness modulus of subsoil G and E. This method can be useful for analysis of the level of vibrations transmitted to the foundations of buildings. They can also be the basis of determination of the necessary stiffness parameters for soil-structure interaction analysis in various problems of dynamics of structures. It can be used to evaluate the stiffness of soil in road embankments. The method is nondestructive (needs no boreholes) and can be fully automatized.

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Keywords: soil stiffness, surface vibrations, vibration measurement, vibration propagation

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1. Introduction

Modelling of geotechnical issues related to the propagation of vibrations in the ground medium requires the adoption of reliable parameters of the subsoil [1]. The most appropriate type of tests to obtain the necessary physical constants of the medium are seismic tests, used in geophysics and based on the determination of the velocity of propagation of shear waves in the ground. This type of tests allows for the determination of shear modulus G and longitudinal modulus E, based on the relationship known from the theory of elasticity. In geotechnics, a down-hole method, known from geophysics, has been applied to penetration testing (invasive) of type DMT and CPTU and the resulting methods: SDMT and SCPTU. Another approach in the area of in-situ methods is the use of surface methods (non-invasive) of type SASW, CSWS or MASW [2]. The main aim of this study was to determine the averaged stiffness modulus of sandy subsoil on the base of analysis of data recorded during the measurement of surface vibration of the ground. The procedure, proposed in this work is similar, to a certain extent, to SASW - a Spectral Analysis of Surface Waves method. The main difference in the proposed method, as opposed to SASW method, is the use of another type of ground load, the use of accelerometers instead of geophones and application of back analysis in place of the most frequently used factored wavelength method.

2. Field studies

Field studies have been conducted on the site of a gravel mine near Bialystok. The study area was chosen for its high homogeneity of the subsoil where, on a large area, low moisture content and medium dense fine sands (fSa) have been found. Free water table was at a depth of two and a half meters. The research plot was flat and even.

As a vibration source used in the tests was the Light Falling Weight Deflectometer (LFWD) type ZFG-01 from ZORN. In the standard approach, this instrument is used to determine stiffness modulus of the subsoil and, indirectly, to control compaction of embankments, even though it is mainly used in construction of transport infrastructure. The deflectometer (LFWD) is a stable and repetitive source of impulse vibration, which in the case of these studies was an undoubted advantage. The device generates a single pulse from the controlled drop of weight of 10 kg from a height of 0.83 m. The stroke is damped by a buffer (a special disc spring). The instrument is subject to a mandatory systematic calibration. Vibration measurements were performed at two points at a distance of 5.0 m and 10.0 m from the source of vibration on the surface of the area. Schematic drawing of the research area is shown in Figure 1.

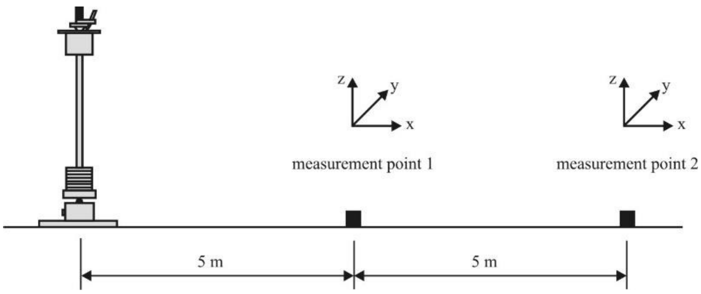

Fig. 1. The schematic drawing of the field test.

Measuring Equipment system was a Siemens type LMS Scadas Recorder. Recording of vibration were carried out on three mutually perpendicular directions: radial *y* (perpendicular to the assumed measurement profile), a radial *x* (in the direction of adopted measurement profile) and in the vertical direction *z*. For each direction, piezoelectric seismic accelerometers type 8340 from Brüel&Kiær were fixed to specially prepared ring bases. The bases were anchored in the ground using three 30-cm anchors. The sensitivity of the accelerometers was 10 V/g and the measuring range ±0.5g in a frequency range of 0.1 Hz – 1500 Hz.

The measuring system LMS Scadas Recorder is shown in Figure 2a. The method of attachment of sensors on the surface by means of the ring base is shown in Figure 2b. In all the test points there were nine two-second waveforms of vibration acceleration recorded.