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Temporal and mathematical methods to evaluate the shear wave travel-time in laboratory tests

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Abstract

The evaluation of shear wave velocity in soil is so much desirable in geotechnical engineering due to its application to estimate the soil moduli under small strain condition. Obtaining the best travel-time is a main concern in calculating shear wave velocity in laboratory tests. Correct travel-time might be masked by some unwanted phenomena such as near-effect. In present paper, basic parameters and specific application of different methods to examine shear wave travel-time i.e. temporal and mathematical methods are explained and their exactitude are comprised. Based on authors' laboratory tests on granular soils, maximum difference between different temporal method results is reached up to 0.09 ms. Cross-correlation presents its best results when the first peak of the received signal is the greatest between all next peaks.

Keywords: Granular soil, Shear wave velocity, Travel-time, Temporal method, Cross-correlation Function.

1. INTRODUCTION

Wave propagation in granular and porous materials has been a main interest of many researchers over recent years. In the field of soil mechanics, wave propagation is a fundamental topic because soil moduli can be found via the properties of wave traversed under small or very small strain level. It has been found that soil elastic moduli can be evaluated by calculation of shear wave (S-wave) and compressional wave (P-wave) velocities propagating through soil [1-8]. This strain level is often observed in soil under dynamic loadings (e.g. earthquake and vibrations of rotating machines) and/or under static loadings, especially on a point far from the load point.

In order to calculate wave velocity, distance traveled by wave and corresponding time must be evaluated. Main concern in the analysis of the wave velocity is obtaining the best travel-time, especially for S-wave due to near-effects [2-4, 9]. There are three conventional methods to evaluate travel-time in laboratory and in-situ tests; temporal, mathematical (cross-correlation), and frequency methods.

Dyvik and Madhus [2] used temporal methods in their bender element test to measure shear wave travel-time in different experimental conditions. Viggiani and Atkinson [3] experimentally evaluated shear wave travel-time in reconstituted samples of boulder clay with various methods such as peak points, cross-correlation function, and cross power spectrum. They concentrated on detection of the first arrival time of shear wave. Jovicic et al. [4] stated that increasing of the input signal frequency may be lead to calculate shear wave travel-time with higher exactitude. Theoretical interpretations of travel-time by Arulnathan et al. [9] revealed that with use of the second arrival in output signal travel-time were least affected by boundaries or transfer functions; however, near-effects still were observed.Recently, many researchers have deeply focused on the wave propagation in the granular materials [10-19].

A new device called bender-extender element proposed by Lings and Greening [10] enables users to determine both S-wave and P-wave velocities in a soil sample. They stated that main problem with bender-extender element was the calculation of shear wave travel-time. Mohsin and Airey [12] tried to find a technique to automate measurement of shear wave velocity. They concluded that the mathematical method (cross-correlation) may give a reliable indication of the travel-time provided the frequency is above some critical values. This critical value increases with effective confining stress. Sharifipour et al. [14, 20] experimentally focused on wave propagation through assemblies of glass beads using bender-extender elements. They used the temporal methods (peak to peak and start to start points) to evaluate shear wave travel-time in bender-extender tests and cross-correlation function as the first indication of the possible