An Experimental Comparison between the Shear and the Plane Waves by Using Resonant Column Test

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ABSTRACT

The resonant column device is commonly used in laboratory to determine the dynamic properties of soils. During the resonant column test, a soil specimen is excited under torsional excitation at different frequencies. In this study, the travel times of the shear (S) and the plane (P) waves were measured on Toyoura sand samples at different relative densities with confining pressures and saturation degrees. Factors effecting on the wave velocities of Toyoura sand samples were investigated by comparing the test results. The variations of the P and S waves are discussed in detail on the basis of experimental results. The study showed that to determine the arrival times of the S-waves and P-waves measured from the soils needs much more laboratory experiments and field test, as well.

KEY WORDS: Resonant Column; Shear Wave; Plane Wave;

INTRODUCTION

The resonant column has been used to determine the dynamic behavior of soils since 1930’s but using resonant column has been popular after 1960’s. The resonant column method was firstly used by Ishimoto & Lida in 1937. Then some researchers such as Hall & Richart (1963), Hardin & Black (1968) and etc. studied the device to determine the dynamic properties of soils. After some improvements and modifications, many researchers are commonly using the resonant column device all over the world. During the resonant column test, a soil specimen is excited under torsional excitation at different frequencies. Test data is obtained as a function of the boundary conditions. The velocity of the propagating wave and the degree of the material damping can be derived by measuring the motion. Shear modulus of the sample can also obtain from velocity and the density.

Determining of the shear wave velocity $V_s$ in soils is substantial to identify dynamic response and liquefaction potential (Richart et al. 1970, DeAlba and Baldwin 1991). Many researchers have been studying to determine shear wave velocity of soils by using field or laboratory tests. For field tests, mainly studies are done by cross-hole tests (Simonini and Cola 2000), down-hole tests (Chien and Oh 2000) seismic reflection and seismic refraction tests (Kramer 2003) and other field test methods. Some parameters such as; shear strain, loading cycles, frequency, confining stress are the variable factors for these tests (Kalinski and Stokoe 2003). For laboratory tests, cyclic triaxial tests (Yunmin et al. 2005), the cyclic simple shear tests (Vaid and Sivathayalan 1996), resonant column tests (Ferreira et al 2006), bender element (Bartake and Singh 2006) tests performed. Void ratio, confining pressure, degree of saturation and the shear strain amplitude are the variable factors and can not incorporate directly, yet.

There are some empirical relationships between shear wave and void ratio, saturation state etc. in literature. However there is no experimental result which incorporated the soil characteristics at the same time (Bartake and Singh 2006). In this study, the travel times of the shear (S) and the plane (P) waves were measured on Toyoura sand samples at different relative densities, confining pressures and saturation degrees. Factors effecting on the wave velocities of Toyoura sand samples were investigated by comparing the test results. The variations of the P and S waves are discussed in detail on the basis of laboratory experimental results.

THEORETICAL BACKGROUND

When a stress is applied to a body, nearest part of the body to the source is affected firstly, and this effect is due to the load spread throughout the body by stress waves (Das 1993). The investigation of the response of particulate materials with longitudinal and transverse wave propagation gives knowledge about fabric, state of stress, fluid – skeleton interaction and permanent affects. Wave parameters can be determined in the laboratory or in the field under different excitation modes and can be modified to the other propagation modes (Fratta and Santamarina 1996). The ratio of P-wave to S-wave velocities gives estimation about lithology changes, because porosity, clay content and the aspect ratio of pores affects this ratio directly. And also the degree of fluid saturation and the frequency content of the wave affect the damping and dispersion for less than $10^{-6}$ strain degrees. Wave velocity in porous media with isolated or interconnected pore spaces can be predicted by mathematical models with general assumptions. On the other hand, experimental studies showed that wave propagations related with saturation and fluid-flow mechanisms can give unpredictable results especially in the compressional mode (Cascante et al. 1998).