Shear Wave Velocity Profiles in Offshore Soils Using the Field Velocity Probe

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ABSTRACT
Shear wave velocity has been commonly used as one of the important design parameters for geotechnical structures which are subjected to dynamic loading. This paper introduces the development and application of a new apparatus, the Field Velocity Probe (FVP) for measurement of shear wave velocity in the field. The shape of the FVP is a blade with two frames, with transducers installed at the tip of the frames. The shear wave velocity is the ratio of the travel distance to the travel time of the shear waves. Thus, no inversion process is required. Penetration tests have been carried out to assess the applicability and disturbance effects in a calibration chamber. In calibration chamber tests, reconstituted clay is mixed with water using a slurry mixer to compose a model soil with a water content of 110%. After consolidation of the reconstituted clay, FVP, downhole, and crosshole velocity tests are carried out at 1 cm intervals during penetration of the penetrometers. The comparison tests produced similar shear wave velocity profiles for each of the apparatus. Shear wave velocity measurements in the field are measured every 10 cm in clay soils up to 30 m by the FVP. The field tests show that the FVP produces a detailed shear wave velocity profile in clay. This study suggests that FVP may be an effective device for measuring the shear wave velocity with minimized disturbance in soft clay.

KEY WORDS: Calibration chamber; Disturbance effect; Field Velocity Probe; In-situ test; Shear waves; Soft soils.

INTRODUCTION
The behaviors of soft clay such as compressibility, permeability, and other properties of saturated soils have become important. In particular, the small-strain modulus ($G_{max}$) is a important design parameter to evaluate the impacts of ground motions due to dynamic loadings such as earthquake, wind, liquefaction, and mechanical vibration. $G_{max}$ can be estimated by shear wave velocity and mass density of the soil (Santamarina et al. 2001).

For the estimation of the shear wave velocity, laboratory and field tests have been carried out. The laboratory tests include bender element tests, dynamic triaxial tests, oedometer tests, and resonant column tests. Shear wave velocity measured by laboratory test methods is very dependent upon specimen condition, and the specimen can be easily disturbed during sampling in the field, conveying from the field to the laboratory, and setting the specimen for small-strain laboratory tests. When properly performed, in-situ testing of shear wave velocity significantly reduces the adverse effects of sample disturbance.

In-situ testing may be divided into two types of methods: non-invasive and invasive. The non-invasive methods use the surface wave to obtain the shear wave velocity profile. The vertical resolution, however, reduces with depth due to the wavelength. Thus, it is difficult to detect a thin layer such as a sand seam within a clay layer. The invasive methods, on the other hand, assess the soil response by using one or two boreholes. Even though the resolution of the invasive method is higher than that of the noninvasive method, the measuring system and analyzing techniques are complex.

The Field Velocity Probe (FVP) was developed to overcome the disadvantages of conventional field tests, and has been modified many times through various laboratory and field tests to measure accurate shear wave velocity with minimized disturbance.

This paper introduces a new device, the Fork Blade-Type FVP, which is the most recent model of the FVP. Laboratory tests were carried out to assess disturbance effects during penetration in a calibration chamber. The shear wave velocities calculated by the FVP, downhole, and crosshole test methods are compared to improve reliability. Field tests were also conducted in onshore clay up to 30 m in depth. This paper describes experimental study, verification tests, and field application tests.

DEVELOPMENT
Field Velocity Probe (FVP)
A schematic drawing and photograph of the FVP are shown in Figure 1. The FVP consists of three parts: connection rod, blade, and two fork frames. The diameter of the connection rod is adjustable from 30 mm to 45 mm, depending on drill rod size. The dimensions of the blade are 120 mm in length, 90 mm in width, and 16 mm in thickness. The shape of the frames is tapered, with the thickness near the blade being 16 mm, and the thickness at the tip being 8 mm. To minimize the soil