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Effect of Collector Touchdown Speed on Dynamic Response of Simulated Deep-Sea Sediments

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ABSTRACT

Though dynamic properties of deep-sea sediments, which are beds of deep-sea manganese nodules, are very important design factors for manganese nodule mining collector, they have not well been examined. A simplified measurement method of the dynamic response of deep-sea sediments was developed. A circular falling collider onto a test specimen and a sub-core sample was used in the method. From the displacement of the collider, the dynamic moduli of elasticity and viscosity were calculated by applying Voigt's model for the sediments. Effect of the falling speed of the collider was also examined onto well-controlled artificial clayey sediments. No significant difference with the speed between 1 m/s and 2 m/s was detected. These results will be applied for the structural design of the collector.

KEYWORDS: Collector design, deep-sea sediment, dynamic modulus of elasticity, dynamic modulus of viscosity, manganese nodule, vane-shear strength.

INTRODUCTION

Deep-sea manganese nodules, which have been found in considerable qualities and quantities at the Clarion-Clipperton Area in the Pacific Ocean, are expected to be one of potential mineral resources of nickel, cobalt, and copper for the next generation. Deep-sea sediments are beds of the nodules, and their geotechnical properties are one of key factors for design of nodule miner, which is called collector. Dynamic response of the deep-sea sediments to touchdown of the collector is considered to be the most important structural design parameter for the collector. Strength of superficial layer of the deep-sea sediments, however, is too weak and sensitive against any kind of disturbance. Therefore, it is very difficult to apply conventional geotechnical tests to them.

The authors developed a simplified measurement method of the dynamic response of the sediments (Yamazaki et al., 1995). A circular falling collider onto a test specimen and a sub-core sample was used in the method. From the displacement of the collider, the dynamic modulus of elasticity was calculated by applying a simple spring model for the sediments. A co-relationship between the dynamic modulus of elasticity and the vane-shear strength was obtained in the study, too.

Different analysis applying a Voigt's model as the sediments is introduced in this study. Effects of falling speeds of the collider are also examined onto well-controlled artificial clayey sediments.

COLLECTOR TOUCHDOWN

Touchdown of the collector on seafloor is only once per a certain period of mining operation. The collector touchdown, however, will be the most sensitive operation of the mining system. Any kind of failures of the mechanisms such as propulsion, nodule pick-up, sediment separation, nodule feeding, monitoring, and controlling caused by a touchdown shock result in a retrieval of the collector and the whole submersible machinery. Plenty of time is required for the recovery of the failures.

The touchdown shock will be considered in the design of the collector frame and each sub-system. Applying a large safety factor is the most undesirable feature of the design, because bearing capacity of the deep-sea sediments is very low and mass of the collector itself increases the shock. Touchdown speed of the collector also increases the shock of course. Dynamic properties of the sediments, however, may be dependent on the speed as the ones of soil investigated by Casagrande and Shannon (1948), and Whitman (1957). A deeper understanding of the dynamic properties of the sediments is required for the design of the collector.

COLLIDER TEST AND NEW ANALYSIS

Principle of Collider Test

A simplified measurement method of the dynamic response of the deep-sea sediments was developed in the previous study (Yamazaki et al., 1995). Base of the method was a measurement of falling distance of a disk collider into a sub-core sample of the sediments. The schematic view of the method is summarized in Fig. 1. The collider was 500 g in mass and 35 mm in diameter. The free-fall height of the collider was set about 15 cm above the specimen in order to get about 1 m/s of the contact speed. The fall of the collider was induced by a release of the lock lever. Displacement of the collider from about 0.05 second before its contact on the sample to the end of collider movement was measured by the electromagnetic conductivity displacement meter. A start trigger of the measurement was obtained from a pass of the lock plate at the electromagnetic proximity switch and all the data were directly stored in a PC through a 12-bit A/D converter. The data was