Assessing Caisson Breakwater Integrity Against Scour Through Ground-Structure System Vibrations

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Taking into consideration the prevalence of rocking vibrations in structures featuring rectangular cross-sections, we introduced an approach for precise determination of the inherent frequencies of such structures. To validate the effectiveness of our proposed method for identifying natural frequencies, we carried out an extensive experimental campaign using a scaled model of a caisson-type breakwater. The study aimed to assess the feasibility of our method in evaluating the structural integrity of the breakwater under varying degrees of scouring. Our findings underscored the potential of microtremor measurements in detecting the advancement of scouring in the caisson-type breakwater.

INTRODUCTION

Ports and harbors are indispensable forms of social capital for supporting economic activities. However, these structures have been damaged by tsunamis and waves, causing them to tilt and subside owing to scouring of the foundation ground (Arikawa et al., 2012). To restore port and harbor activity earlier, the integrity of the structures post-damage must be evaluated as soon as possible in a quick and simple manner using overwater diagnosis. Oumeraci (1994) classified the damage from vertical breakwaters as overall global and local failures. The progress of the local failures can lead to overall failures. Therefore, integrity monitoring of the existing caisson structures is necessary. Natural frequency has often been used as an index to evaluate the soundness of structures (Kariyawasam et al., 2020; Lee et al., 2020; Belmokhtar et al., 2021). Natural frequencies of the caisson due to impact excitation by a rubber hammer were investigated at different damage levels of the foundation mound (Lee et al., 2012; Lee and Kim, 2015; Zhang et al., 2016). An attempt to identify experimental modal parameters of wharf structures was also made using microtremors produced by tides, wind, and waves (Boroschek et al., 2011). However, studies on evaluating the vibration characteristics of caissons using microtremors are limited. This is because the vibration level of a caisson is lower than that of a port structure. Microtremor observations are conventionally used as a method that does not require impact excitation. However, they are occasionally ineffective because the peak in the observed Fourier spectrum of the structures is often unclear (Masui et al., 2008).

Therefore, we employed a new microtremor observation method in this study. We focused on the fact that rocking vibration is dominant in structures with rectangular cross-sections and proposed a method to identify the natural frequencies of structures with high accuracy (Watanabe et al., 2020). In this previous study, microtremor measurements were conducted on 12 river piers with high accuracy (Watanabe et al., 2020). In this previous study, we demonstrated the efficacy of the proposed method through a comparison with the conventional approach, which extracts the dominant vibration frequencies of the Fourier spectrum of the microtremor of the caisson. Microtremor measurements using the conventional method are susceptible to the influence of input vibrations from the ground, potentially rendering the measurement of structural vibrations in the target object difficult. To address this, we conducted experiments by varying the conditions of input vibrations from the ground to the caisson foundation, showcasing the robustness of the proposed method under diverse input vibration conditions. Another originality of this study is that it attempts to capture the progression of scouring of the ground around the structure at the center of rotation of the rocking vibration calculated during the process of identification of natural frequencies.

OVERVIEW OF NATURAL FREQUENCY IDENTIFICATION METHOD USING MICROTREMOR MEASUREMENTS

In conventional microtremor measurements, which simply read the predominant frequency of the Fourier spectrum of the measured waveform, it is difficult to identify the natural frequency when the input vibration from the ground to the structural foundation is greater than the response vibration of the structure. Therefore, a method for identifying natural frequencies using microtremors has been proposed to reduce the influence of the input vibration from the ground on the foundation of the structure (Watanabe et al., 2020).

Figure 1 shows the identification flow of natural frequencies using the proposed method, while Fig. 2 depicts the image of Fourier spectrum processing in the proposed method. The step numbers in Figs. 1 and 2 correspond to one another.

In Step 1, microtremors in the vertical and horizontal directions are measured at both top edges of the caisson, as shown in Fig. 3.