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Feasibility study of using acoustic emission signals for investigation of pile spacing effect on group pile behavior

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ABSTRACT

Understanding the subsoil behavior subjected to group pile loading is of foundation important to clarify the group pile behavior. The acoustic emission (AE) signals produced by the stressed subsoil subjected to group pile loading are expected to contain useful information about the behavior of group pile. In this study, measurements of AE signals generated during group pile loading were performed. To evaluate the effect of pile spacing, group pile loading tests were performed with two different pile spacing to represent strong and weak group effects. Results showed that the group pile in case of narrow spacing might significantly reduce the apparent stiffness of the ground, which was evidenced by lower values of ground secant modulus and the released AE energy. In addition, center pile carried more load and emitted higher level of AE compared with other pile positions when the pile spacing was narrow. However, it is observed that such group pile effect was affected by the loading history as well. Considering the high consistency between the results of conventional load-settlement measurement and the AE monitoring, it is therefore suggested that the AE monitoring can be potentially used as an alternative method for evaluation of the group pile behavior.

1. Introduction

Group pile has been a common design in modern infrastructure constructions. It is well acknowledged that the capacity of group pile depends on the individual pile capacities, and is influenced by the spacing between the piles [1–3]. There exists a certain value of pile spacing at which the mechanism of group failure changes [4–7]. For those spacing larger than this value, the failure of group pile is analogous with local penetration of individual piles; for those spacing smaller than this value, the failure of group pile occurs together as a block. Therefore, it is suggested that the pile spacing should be as large as practicable to avoid significant pile interaction. However, close pile spacing is practically unavoidable and accordingly the group pile effect has to be considered during pile foundation design. Although the importance of clarifying the group pile behavior has been well recognized, there is a general lack of scientific understanding about the effect of pile spacing on the behavior of group piles. Overall, the empiricism remain plays an important role in the current practice of group pile design [8].

Conventional pile studies focus on load-settlement measurement. Such measurement, however, does not provide enough information for more refined investigation of the stressed subsoil behavior. With the increasing demand on further understanding of pile bearing behavior, some recent studies have made attempts to investigate the subsoil behavior near the pile end [9–14]. In particular, some novel approaches such as the X-ray CT and the particle image velocimetry (PIV) enabled direct observations of stress and strain distributions of subsoil subjected to group pile loading [15,16], which provided close inspections into the subsoil behavior in a nondestructive way. However, it should be noted that the X-ray CT or PIV method is only possible in a laboratory setting condition.

The objective of this study is to evaluate the feasibility of using the signatures of Acoustic Emission (AE) signals to investigate the group pile behavior. The AE monitoring method has been introduced into a wide variety of applications with different materials including metal, rock, concrete and composites [17–20]. Although the AE method does not receive widespread popularity for monitoring of porous granular soils, it has brought many insightful results in a variety of successful applications such as triaxial compression of soils [21], soil seepage and erosion measurement [22,23], and slope stability measurement [24].The basic concept behind AE monitoring during pile loading is that when soils below the pile tip are stressed, AE signals are generated due to sand particle movements, surface grinding or individual particle

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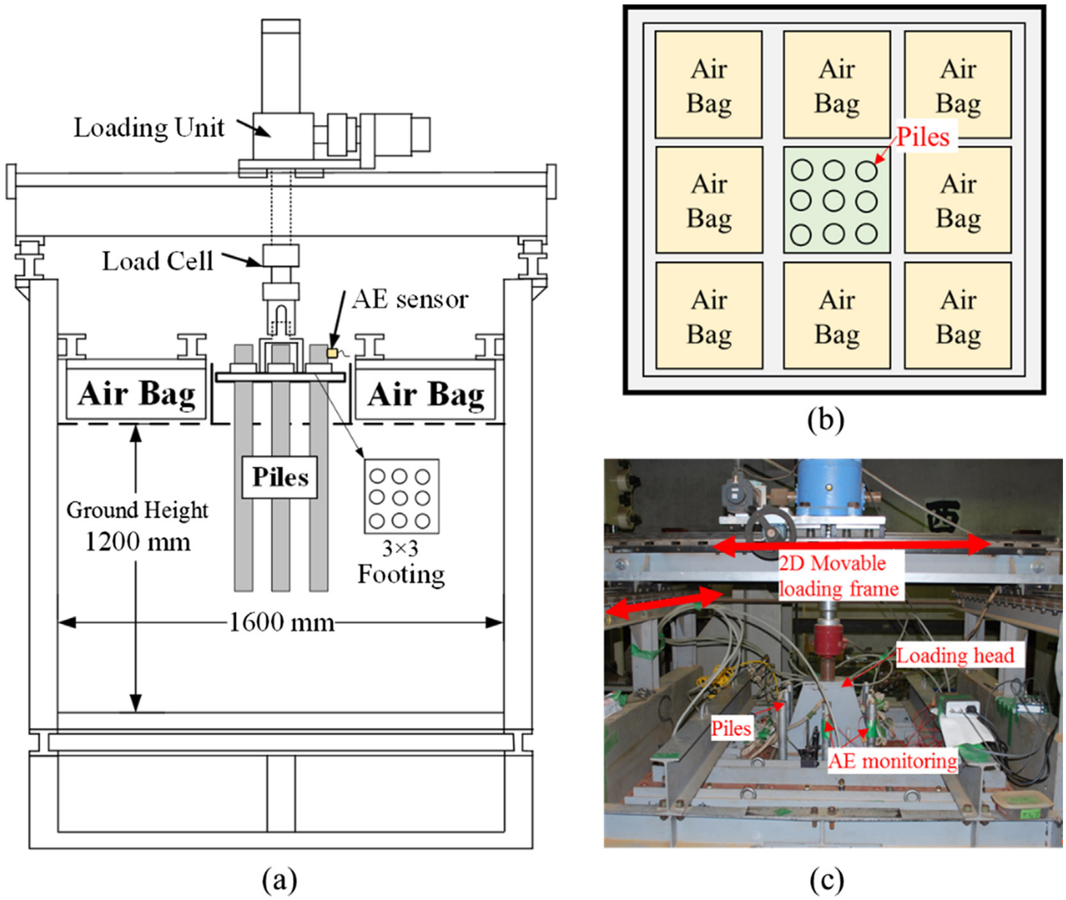

Fig. 1. Schematic diagram of the group pile apparatus: (a) front view; (b) top view of pile locations and air bags; (c) overall picture of the experimental setup.

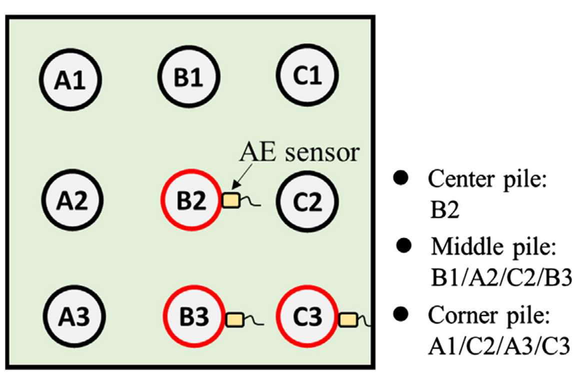

Fig. 2. Definition of pile positions among the group and the selected piles for AE monitoring.

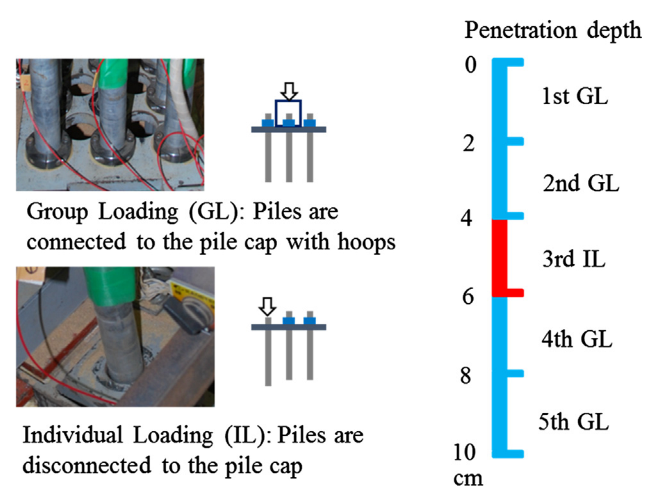

Fig. 3. Illustration of group loading and individual loading processes and loading steps.

breakage. In case of group pile situation, previous studies generally found that narrower pile spacing had more significant effect on group pile behavior [5–7,16]. When pile spacing changes, the interlinked local soil properties will also change during the process of group pile loading. These changes would be eventually featured by different AE characteristics. To investigate the acoustic phenomena for different pile spacing conditions, two types of pile spacing, 2.5D (2.5 times of pile diameter) and 5D, are tested in the current study to represent strong and weak group effects. The AE signals detected from these two cases are analyzed in terms of different parameters and the feasibility of the applicability is accordingly evaluated.

2. Experimental details

2.1. Setup of apparatus

The schematic diagram and the general layout of the testing apparatus are shown in Fig. 1. The soil tank has an inner dimension of 1600 mm (width) × 1600 mm (length) × 1680 mm (height). The group pile model used in this study is constituted of 9 piles (3 × 3), and is located in the center of the model box. For axially loaded piles, previous studies [10], [13] suggested that the intense stress and strain