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Application of a Pile with an Expanded Base to the Foundation of a Caisson Structure

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ABSTRACT

The dynamic response of a caisson-type structure resting on a pile foundation to attack by storm waves was evaluated numerically by FEM (finite element method) analysis in order to investigate the feasibility of a pile with an expanded end to support offshore structure foundations. The caisson-type structure, such as a caisson breakwater, caisson-type seawall, dike, dolphin, quaywall or jetty, was assumed to be a linear and elastic solid, and its foundation was assumed to be a linear, elastic and permeable medium to simulate normally consolidated soil. The displacement and the pore water pressure around the piles were estimated numerically while varying the number of piles under the caisson, the distance between piles and the connection between the caisson and the piles. This type of pile foundation prevents the generation of excess pore water pressure beneath the caisson. The connection between the caisson and the piles becomes more important as the uneven settlement and rocking increase.

INTRODUCTION

Port structures such as quays and jetties are important for moving goods to/from overseas. The importance of port structures increases especially after earthquakes. The severe shock from an earthquake crushes the infrastructure of port communities such as transportation, telecommunication, lifelines and buildings. These entities are crucial for the rapid recovery and supply of (1) food and water, (2) emergency goods, (3) construction materials, (4) workers and (5) accommodations. It takes several years to completely restore the infrastructure of port communities after an earthquake. In addition, emergency rehabilitation has also been shown to take a considerable amount of time. The mass transportation of goods and people by shipping becomes the principal means to supply a large amount of relief goods and commodities to port communities. Occasionally, large ships in the ports are used to accommodate people who have lost their homes to an earthquake or serve as emergency departments. Shipping can also be used for emergency evacuation. Therefore, the design of seismically resistant port structures is vitally important. Also, we must consider new ways to reduce the cost of construction, while increasing the structural resistance of the port structures to attack by strong waves or earthquake ground motion.

Takatani et al. (1996) have evaluated the dynamic response of a caisson-type structure to suction. In another study, they investigated the efficacy of a steel caisson with a skirt in withstanding the forces generated by strong waves. In this paper, we investigated the resistance of a caisson on a pile foundation against strong waves equivalent to the horizontal acceleration force generated by earthquakes.

The investigation of the damage caused by the 1995 Hyogo-ken Nanbu Earthquake (the Kobe Earthquake) revealed that most of the quays were damaged. The damage was triggered by the large acceleration forces generated by the earthquake. This earthquake produced seismic forces almost equivalent to the mass of the structure times the earthquake-induced horizontal acceleration. These forces exceeded the maximum horizontal force allowed under the design of the quays.

Because of the costs of construction, the port and harbor structures were not designed to resist either waves in the open sea or the horizontal acceleration forces generated by an earthquake beyond 250 gal. Therefore, the cost-performance construction method is required to raise the resistance of such structures to earthquakes. Some of the pile-supported jetties survived the severe horizontal acceleration forces generated by the Kobe Earthquake. This suggests that piles increase the resistance of port structures against earthquakes. Therefore, the use of bearing precast concrete piles with an expanded base has been proposed for the foundations of retrofitted caisson-type structures.

In order to investigate the feasibility of a pile with an expanded base in withstanding the acceleration forces generated by an earthquake, we evaluated the response of a caisson breakwater by FEM analysis. We also investigated the feasibility of such structures as the foundations of port and harbor structures, such as

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