ABSTRACT

The main aim of this paper is to assess behavior of existing caisson type quay wall, which is upgraded by deepening front water depth, using numerical analysis. To upgrade the quay wall, the rubble mound under the front caisson toe is solidified by grouting and then cut until the design level. The numerical analysis is carried out by the finite element method (FEM) program (PLAXIS 2D-2018). From the results, the change of stress in the rubble mound before and after upgrade can be evaluated. Besides, the analysis also indicates the difference of quay wall displacement estimated from distinct soil models.

KEYWORDS: Deepening, gravity quay walls, grouting, grouted rubble, front water depth

INTRODUCTION

Quay walls are earth retaining structures at which ships can berth. They are usually equipped with bollards to provide moorings for ships and fendering to absorb the impacts of the vessels. The quay walls are used for the transshipment of goods by cranes or heavy equipment that moves alongside the ships (De Gijt and Broeken, 2005). The quay walls used in reality are very distinct from structure types, but in general, they can be classified into four basic types including gravity walls, sheet pile walls, structures with relieving platform and open berth quays as shown in Fig.1.

Nowadays, with the significant increase of big vessels, the requirement for transportation of goods and passengers by waterway is also rising rapidly. This leads to the demand for the deep-water ports to become more and more necessary to berth these ships. However, many existing quay walls were built in the history having low front water depth. These mooring facilities are becoming backward and cannot meet current development. Besides, because of the high cost and the environmental problem, the total demolition of these existing quay walls and construction the new structures are not a reasonable option. Thus, upgrading by increasing the front water depth of the existing quay walls is a suitable solution from both engineering and economic views.

Regarding this problem, a series of studies about the deepening and innovation of the existing quay walls have been presented in the literature. Elsken and Bols (1998) indicated that combining the techniques of the very high-pressure grouting, installation of ground anchors and drains had already proven to be an economical and technical solution for deepening the quay walls. Bauduin et al. (2017) proposed some general guidelines for an integrated design and construction approach, combining risk fault tree analyses, robust and flexible design, construction methods and monitoring methods. Oung and Brassinga (2015) discussed widely the risks of upgrading the existing quay walls such as deepening in front of quay walls and increasing the loads on the quay surface. Ruggeri et al. (2019) summarized the main issues involved and experiences in geotechnical design for upgrading six quay walls to meet new demanding requirements in Italy. Galal (2017) carried out a numerical analysis for upgrading the container terminal with an open berth on pile type structure in Egypt. Cornell et al. (2007) presented the solutions and experience to innovate the berth structure in the Panama Canal. The structure was strengthened by an additional structure system including piles and sheet piles before excavating the sea bed to increase water depth. Both Mizutani et al. (2013) and Oh (2017) used a grouting method to improve rubble mound before excavating to increase water depth. Various numerical analyses and some dynamic tests such as the sharking table or centrifuge tests were conducted to access static and seismic behavior of the caisson type quay wall after enhancement. Douairi and De Gijt (2013) introduced a series of concepts for creating the water depth of sheet pile walls such as using extra grout anchor, grouting in front of the quay walls, using additional sheet pile. El-naggar (2010) studied how to enhance steel sheet walls using grouted anchors by the FEM method and evaluated the effect of some factors on the upgrading of this type of wall.

The researches focusing on the upgrading of the gravity quay walls are still limited, especially considering the detail behavior of the structures and rubble mound. Therefore, this paper aims to innovate a gravity quay wall with caisson-type structure. To deepen this facility, a part of the rubble mound beneath the caisson toe is solidified, then excavated to increase the front water depth. The study assesses the static behavior of the quay wall by numerical analysis using the PLAXIS 2D program. In order to evaluate the influence of the soil model on the displacement estimation of the caisson, the Mohr-Coulomb (MC) model and The Hardening (HS) soil model are used in the numerical analysis. From the results, the change of stress in the rubble before and after innovation can be evaluated. In addition, the displacements of the quay wall during construction and operation are also estimated for both soil models.

2D Finite Element Method Analysis for Deepening of Existing Gravity Quay Walls

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