Study on the Anti-Floating Stability of Monolithic Lock Chamber with Lateral Slabs

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ABSTRACT

A new type of the monolithic lock chamber with lateral slabs has been gradually used in lock engineering, because it has the advantages of reducing the earth pressure on the chamber wall and increasing the anti-floating stability of the chamber. Anti-floating stability during lock maintenance is a key issue in structural design and needs to pay special attention. Based on an engineering case, a finite element numerical model combined with a loading coefficient method is established to investigate the anti-floating stability of monolithic lock chamber with lateral slabs. A computing method of the anti-floating stability safety coefficient is proposed, and its feasibility is demonstrated.

KEY WORDS: Monolithic lock chamber with lateral slabs; anti-floating stability; loading coefficient method; finite element; safety coefficient.

INTRODUCTION

Unloading structure is widely used in wharf, highway, railway subgrade and slope protection (Zhu, 2019; Cai, 2020; Li and Wei, 1998) but less used in ship lock engineering. In recent years, lateral slab has been gradually designed in the lock chamber to reduce the earth pressure on the chamber wall and increase the anti-floating stability of the chamber (Jiang and Li, 2016). A new type of the monolithic lock chamber with lateral slabs has been proposed in lock engineering. Previous studies on this kind of structure are mainly focused on the influence of lateral slabs to the structural mechanical characteristics, while research on the influence of anti-floating stability is relatively few (Zhang et al., 2019; Xi et al., 2018).

The anti-floating stability safety coefficient in the Code for Design of Hydraulic Structures of Ship Lock (JTJ 307-2001) is defined as the ratio of the sum of vertical forces to the sum of uplift pressures. However, the sum of vertical forces in monolithic lock chamber with lateral slabs is unclear in calculating. The strength reduction method is used to analyze the anti-floating stability of the underwater pipeline, but this method is not applicable to monolithic lock chamber with lateral slabs (Zhu et al., 2019; Zhao et al., 2020). Based on the loading coefficient method, analysis on the anti-floating stability of monolithic lock chamber with lateral slabs is done in this paper.

The loading coefficient method is proposed in the study on stability of the bucket foundation breakwater structure (Xiao et al., 2009). In this method, the wave force is gradually increased in the calculation of numerical simulation until the instability of the structure, and the wave force at this time is the ultimate bearing capacity of the structure.

During the analysis on the anti-floating stability of monolithic lock chamber with lateral slabs, a finite element numerical model is established, and an initial equilibrium state is formed through eliminate the displacement caused by dead weight of the soil and structure. The uplift pressure is loaded step by step according to the distribution of uplift pressure until the finite element calculation does not converge. Based on the instability criterion, the ultimate uplift pressure of the structure is obtained, and the safety coefficient is defined as the ratio of the ultimate uplift pressure and the designed uplift pressure.

NUMERICAL SIMULATION AND VERIFICATION

Numerical Model

The structure of monolithic lock chamber with lateral slabs is used in Nanping Shiplock, Anhui Province. The cross-section view of the structure is shown in Figure 1. The height of the chamber is 15m, the width is 28m, the effective width is 21.2m, and the thickness of bottom plate is 2.4m. The top width of the chamber wall is 0.8m, the bottom width is 2.4m. The lateral slabs are located 7.5m from the top of chamber wall and the width is 2.2m. Two longitudinal drainage pipes are set behind the chamber wall, which are connected by horizontal drainage pipes, and the elevation of the drainage pipe is 18m. Other dimensions are shown in Figure 1.