Research Advances

Study on the Submarine Slope Stability of the Deep Channel in the Caofeidian Harbor

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Objective

The greatest advantage of the Caofeidian Harbor is its deep channel facing the Bohai Bay. The deep channel is a natural port hub for shipping of the Caofeidian Habor. The construction of the Caofeidian Harbor has impacted the hydrodynamic environment and the sediments movement, which has attracted much attention about the geomorphic evolution, slope stability and the evolution trend after submarine slope destruction. Insight from this study might be significant for the future development of the Caofeidian Habor, including planning, operation and maintenance.

Methods

This study describes the geomorphic features in the deep-channel sea area based on the multi-period water depth data and side-scan sonar survey data. In order to analyze the historical origin of the Caofeidian Channel, we carried out the fine interpretation of shallow seismic profile, single-channel seismic profile and multi-channel profile integrated with the high-resolution and high-SNR (signal-to-noise ratio) seismic profiles. We conducted submarine slope stability assessment using the limit equilibrium analysis methods and the slope reliability quantitative evaluation by numerical simulation and probability method.

Results

(1) Comparing and analyzing the water depth data from the sea area of the deep channel in 2004, 2008, and 2013, the results indicate that the depth contour is generally unchanged, there is no obvious shift in the shaft position and the depression area undergone gentle erosion. In the recent decade, the deep channel is characterized by the 35

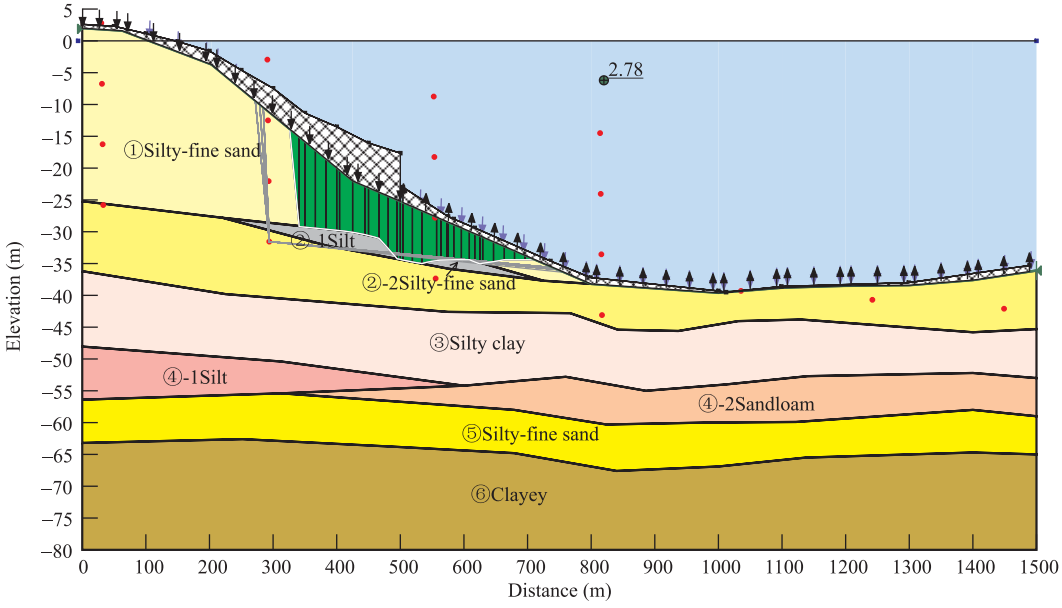

Fig. 1. Schematic diagram of the submarine slope stability after construction of the Caofeidian ore terminal.

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m isobath moving southward by approximately 100 m, the 40 m-isobath area increased by 30% and the maximum erosion rate is 19 cm/yr.

(2) The occurrence of landforms in the Caofeidian Channel sea area is jointly controlled by endogenic processes (i.e. geological structure and evolution of the ancient Luanhe River delta) and exogenic processes (i.e. ocean hydrodynamics and human activity). The formation of landform is predicated on the subsidence of the deep seafloor structure. Induced by ocean hydrodynamics, the ancient Luanhe River delta gradually evolved, thus forming the Caofeidian headland. Affected by the modern construction of the Caofeidian, deposition occurs at the tidal beach and the channel gets eroded.

(3) Before the construction, the submarine slope remains stable due to the self-gravity load. In contrast, after the construction, building load increased, resulting in a lower degree of safety for the submarine slope. However, results reveal that the degree of safety is still relatively high and the submarine slope remains stable.

Conclusions

(1) The ancient multi-stage river channel present in the Caofeidian Channel is characterized by a cross-mesh structure. Based on this result, we demonstrated that the Caofeidian Channel has evolved through 20,000 years at least, and experienced N−S, N−E and N−W trending transformation.

(2) Storm surges, waves, earthquakes and other external forces severely affected the submarine slope stability. The degrees and locations of destruction by these sensitive factors are different. Storm surges and waves mainly damage the shallow surface of the submarine slope with a relatively-lower degree; seismic forces dominantly destroy the mid-deep strata of the submarine slope with a relatively-higher degree. However, only Ms>8 earthquakes will affect the safety of the submarine slope.

(3) The submarine slope stability is also related to soil strength, terrain and other inherent factors. The submarine slope stability decreases according to the soil strength index values of c and φ reduce.

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