The impact of dike construction on the flow and sediment siltation in the project of Meishan Container terminal phase II

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Abstract. In order to avoid the adverse impact of Qinglongshan deep groove on the flow pattern of the Meishan Container terminal phase II ensuring the safety of berthing, a submarine dike is proposed along the land front direction toward the Qinglongshan Island. The influence of different dike layout schemes on the water flow in the surrounding sea area was studied through the mathematical model. In addition, the effects of different dike heights and gap width on the surrounding water flow and siltation were analysed. The results show that the crossflow in front of the terminal under the two submerged dike heights and gap widths are basically the same, which is less than that of without the construction of the dike. Appropriate reduction of dike height is conducive to improve the flow at the channel between the Qinglongshan and Meishan Island. After the dike construction, the groove will maintain a certain depth, and will not result a blocking at the top side of dike and the rear channel.

1. Introduction
Ningbo-Meishan port area has good water and land conditions to construct large-sized container berths. In the southeast of Meishan Island, a container terminal phase I has been built and already put into use [1]. In the north of container terminal phase II, there exist a deep groove between Qinglongshan and Meishan Island (figure 1). The tidal current of the deep groove obliquely pierces the water area in front of the wharf making the flow at the southeast side of the wharf disorder, and the large local cross-flow can influence the use of the dock [2]. In order to ensure the safety of ship berthing and load-unloading operation, the embankment construction along the land front line along the direction of Qinglongshan Island was proposed. The project will smooth the tidal current around the terminal area, and resulting a small crossflow in front of the wharf. However, the impact on the topography for the area behind the Qinglongshan Island is not known. Will the construction of dike causes a damage to the island landscape? This paper tries to analyze this problem from the perspective of sediment movement and landform evolution.
The local hydrodynamic conditions will be adjusted after the construction of the dike between the Qinglongshan Island and the terminal. Which can significantly reduce the velocity at the water area behind the Qinglongshan Island. The slow velocity water area will result a rapid deposition of sediment. In this study, the sediment siltation after the project will be modelled using a mathematical model, and the influence of different dike heights and gap widths on the surrounding water flow and siltation will be discussed.

2. Mathematical model establishment and verification

2.1. Model verification

The numerical model is DHI MIKE21 [3]. In order to simulate the tidal dynamics of the sea near the wharf, a model nesting method was adopted to provide the open boundary tidal condition [4]. The water depth distribution of the model is shown in figure 2, and the mesh of the mathematical model calculation is shown in figure 3. The triangular meshes are used to fit the irregular coastlines. The grid resolution is about 20m near the coast, the number of grid cells is 34488, and the number of nodes is 18556.

The mathematical model was verified by comparing the water level and flow velocity to the measured data. The tidal, tidal current locations of the measuring point are shown in figure 2, arranged 10 tidal current and 4 tidal elevation measurement points. Figure 4 shows the results of tide verification at four tidal level sites and it can be seen that the simulation error is less than 0.1m, and the tidal wave phase coincides well with the measured results. Figure 5 shows the verification result of the flow velocity and direction of spring tide. Due to the large number of islands and the complicated topography, the flow pattern in this area is complicated. From the simulation and the measured results, the flow at the points of 1, 2, 5, 6 and 7 show the swirling pattern. While the flow of other points show the reciprocating pattern. Points 1, 2, and 3 are different in the flow direction, at the point 3 the flow is reciprocating flow due to the boundary constraint, and the flood velocity is 1 times larger than that of ebb velocity at 3. In the vicinity of the project area (9), the tidal current is strong and the flood-ebb velocity is about 1.50 m/s during the spring tide, with its flow direction parallel to Meishan terminal Phase I shoreline.

From the verification results we can see the model simulate the tidal current very well compared to the observed data, which indicates that the boundary conditions provided by the mathematical model and the values of the model calculation parameters are reasonable and correct.
Figure 2. Calculation area and locations of the verification points

Figure 3. Computational mesh
3. Influence of dike construction on water flow and sediment siltation

3.1. Design cases description
Considering the effect of different dike schemes on the improvement of cross flow along the front of the wharf, and the influence on the siltation between Meishan and Qinglongshan Island, four cases were designed (figure 6).
3.2. **Analysis of water flow characteristics between Qinglongshan and Meishan Island under different cases**

Under the land constraints of the second phase terminal, the forefront flow is parallel to the forefront of the pier. In the tidal grove between Qinglongshan and Meishan Island, the flow velocity is relatively large. After the second phase construction, the flow in the channel between Qinglongshan and Meishan Island has weakened and influence scope can reach the north of Meishan Island [5].

The local flow velocity near Meishan Island in Qinglongshan is slightly different from that before the project. The analysis shows that although the embankment dike has been constructed from case 2 to case 4, the flood and ebb flow pathway mainly at the outside Qinglongshan. The flow velocity inside the channel is relatively small.

In order to further understand the influence of the embankment project on the surrounding water flow, the flow pattern of the maximum northeast and southwest flow velocity in the channel are added. Taking the comparison of the case 1 and 2 as an example (figure 7). From the comparison between the moments of the maximum northeast flow velocity occurs in the channel we can see that as the embankment is not built, the flow velocity in the channel is large and the flow direction is parallel to the channel axis. After the completion of the embankment dike with the top height equals 2.2m, the water flow is smooth in front of the terminal. As the maximum southwest flow occurs in the channel (figure 7b), the construction of the embankment project enhanced the smoothness of the water flow at the frontier of the land area, and the flow velocity in the channel was greatly reduced. The embankment dike construction has little effect on the flood current (figure 7c). In case 1, the water flow is strong at the northeast corner of the newly reclaimed land area and forms a recirculation area at the foreland of the land area (figure 7d). After the closure of the embankment dike, the flow becomes smooth and the flow velocity has increased, which is conducive to reducing the back of the terminal siltation.

In contrast to the instantaneous flow patterns of the case 2 to case 3, it is found that there is little influence on the flow pattern in the other areas except for the local water flow near the gap.

In the case 4, when the height of the embankment dike is lowered (85 datum in elevation of 0 m), the flow velocity in the channel is a little smaller than that without the construction of the dike, but the dike can also smooth the frontier water flow at the terminal resulting a small cross section velocity.

The maximum velocity of northeastern and southwest flow in the channel occurred during the high tide period, and it was inconsistent with the flood and ebb tide time of the outer channel of Meishan Island. The construction of the embankment dike could increase the smoothness of water flow in the

![Figure 6. The 4 design cases](image)
foreland of the terminal land area. The decrease of dike height is helpful to increase the water flow in the channel between Qinglongshan and Meishan Island and to reduce the siltation.

(a) ~ (d) are the maximum instantaneous velocity of northeast and southwest of Qinglongshan and Meishan Island, and the flood, ebb outside the Meishan Island

Figure 7. Comparison of Instantaneous flow between case 1 and 2

3.3. Sedimentation for the 4 cases

The annual silt distribution is calculated by mathematical model [6], and figure 8 shows the annual siltation for the case1–case4 respectively. After the implementation of case 1, the local maximum sedimentation is about 3m in the tidal channel between Qinglongshan and Meishan Island due to the relatively high sediment concentration before the project. After the implementation of case 2, the construction of dike makes the flow velocity within the channel between Qinglongshan and Meishan Island decrease obviously, and the siltation within the channel is strengthened. The distribution of siltation for the case 3 is basically the same as that of case 2, and the degree of siltation is reduced only near the gap inside the embankment. After the implementation of case 4, the dike height decreased from 2.2 m to 0 m, and the flow velocity in the tidal channel between Qinglongshan and Meishan Island increased significantly compared with those in case 2 and 3, which resulted in the siltation within the channel significantly weakened.
In general, with the increase of siltation, the local cross-section area is reduced, resulting the flow velocity increased, and the new cross-section depth will be maintained. The siltation at the two sides of dike will gradually reach the balance. Due to the maintenance of water and wave dynamics, and with a certain amount of tide volume and overhead flow above the dike, the channel between Meishan and Qinglongshan Island will not silt to death.

![Figure 8. Distribution of siltation for the cases 1 to 4 respectively](image)

### 4. Conclusions
The influence of the Qinglongshan embankment on the water flow in the surrounding sea area and the siltation between Meishan Island and the Qinglongshan channel on the backside of the embankment are analyzed by mathematical model. The conclusions are as follows:

1) The construction of the embankment dike project slow down the flow velocity in the channel between Qinglongshan and Meishan Island. With the decrease of the height of the embankment dike, the flow velocity in the channel increased. The maximum velocity in the channel is about 0.50 m/s when the elevation is 0m, which increases obviously compared to the elevation of the embankment equals 2.2m.

2) The crossflow after the construction of the dike embankment decrease to 0.23 m/s. The amount of siltation can be decreased after the decline of the dike height. The influence of different gap width on the distribution of back siltation is only limited to the area near the gap.
3) With the increase of siltation, the local cross-section flow velocity will be increased, and thus maintain a new section depth. With the combination effect of the flow and wave dynamics, the grove will not be disappeared after the dike construction.

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