Research on the settlement of deep water submerged dike structure

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Abstract. The 12.5 m deep-water channel from Nanjing to mouth in the Yangtze River is a national key channel. This paper analyzed the settlement feature of deep water submerged dike structure in He changzhou waterway section based on in-site tests. The settlement was recorded and a fitting function to predict the long-term settlement was proposed.

1. Introduction
More and More in-land deep-water channels were constructed to meet the need of rapid economy development. In order to maintain the operation of deep-water channels, real-time monitoring on key nodes settlement should be proposed to grasp the dynamic information of channel situations. While deep-water channels are always accompanied by the feature of large depth, mass flow and no advection period, the in-site monitoring especially real-time monitoring during the storm is a big challenge.

This paper analyzed the development of deep-water submerged dike structure settlement based on in-site testing in He changzhou waterway section. The fitting function to predict long-term settlement was established to guide the engineering practice.

2. Profile of the engineering case
Two flat submerged dikes crossing waterway section were installed in the waterway improvement engineering of He changzhou waterway section. The submerged dike 1# locates at 2100 m downstream of a built-up submerged dike, and the submerged dike 1# locates at 1000 m downstream. The elevation of dike crown varies much. The sections connecting to two shoresides are +4.0 m and +6.0 m, while the elevation of dike crown in the deep-water channel is -18.0 m. Three GK-4600 type settlement monitors were installed in each cross-section of the dike, and the locations of monitors is shown in Fig.1.
Considering of the feature of large depth, mass flow and no advection period, flat-deck vessels above 3000 tonnage with front and rear splay anchor positioning (The anchoring force should be larger than 10 tons) were chosen to overcome the influence of current and wave, offering a stable operation platform. Drilling machine above type 150 were selected to produce enough drilling power and depth. A 4.0 m wide and 6.0 m long operation platform should be set-up for the operation of drilling machine. The flat-deck vessel used in practice was shown in Fig.2.

The monitoring lasted from March 4, 2016 to December 18, 2016, and the construction of submerged dike main structure finished before June, 2016.

3. Testing results
Fig.3 shows the development of settlement with testing time, and the specific value of settlement and maximum settling rate is listed in Table 1.
Figure 3. The development of settlement

| Monitoring site | 1#  | 2#  | 3#  |
|----------------|-----|-----|-----|
| Total settlement (mm) | 227.3 | 187.5 | 117.7 |
| Maximum settling rate (mm/d) | 68.4  | 42.8  | 16.9  |

The total settlements of monitoring site 1#, 2# and 3# are 227.3mm, 187.5mm and 117.7mm. The settlement in midpoint of submerged dike cross-section is maximum. The maximum settling rate of submerged dike cross-section midpoint is 68.4 mm/d, greatly exceeding the critical value of 20 mm/d. But the maximum settling rate lasted for just a short moment, only existing in the riprap construction duration, and the settling rate reduced rapidly as soon as the finish of riprap.

The hyperbolic curve fitting method is used to predict the long-term settlement, and the fitting function is shown as followed.

\[ S_t = S_0 + \frac{t}{\alpha + \beta t} \]  
\[ S_\infty = S_0 + \frac{1}{\beta} \]  

Where, \( S_t \) is the settlement at time point \( t \), mm; \( S_0 \) is the settlement at the beginning of construction, mm; \( t \) is the construction duration, d; \( S_\infty \) is the final settlement, mm.

The parameters \( \alpha \) and \( \beta \) in fitting function could be obtained using the in-site testing data with inverse computation. And the values of \( \alpha \) and \( \beta \) for monitoring site 1#, 2# and 3# are calculated as Fig. 4, 5 and 6 shown.
The consolidation degree could be calculated as followed.

\[ U_t = \frac{S_t}{S_\infty} \times 100\% \]  

Where, \( U_t \) is the consolidation degree at timepoint, \( % \); \( S_t \) is the settlement at timepoint \( t \), mm; \( S_\infty \) is the final settlement, mm. The consolidation of monitoring site 1#, 2# and 3# is in Table 2.

| Monitoring site | 1#     | 2#     | 3#     |
|----------------|--------|--------|--------|
| Consolidation degree (%) | 90.6   | 90.7   | 90.1   |

The predicted consolidation degrees of monitoring site 1#, 2# and 3# reached 90.6%, 90.7% and 90.1%. The compression deformation of soil has been basically completed at the end of monitoring test.

4. Conclusions

Based on the in-site tests, the settlement feature of submerged dike can be obtained. The main conclusions are as followed.

- The settlements of monitoring site 1#, 2# and 3# at the end of in-site testing were 227.3mm, 187.5mm and 117.7mm. The largest settlement exists at the midpoint of submerged dike.
- The consolidation degree of monitoring site 1#, 2# and 3# at the end of in-site testing reached 90.6%, 90.7% and 90.1%. The compression deformation of soil has been basically completed at the end of monitoring test. Few settlements would occur in the post-construction period.
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