The project design of closure with cofferdam in a large reclamation project

JIN Hai-sheng[1], XU Ji[2] and GE Guo-chang [3*]

[1]Wenzhou Oufei development and Construction Investment Group Co. , Ltd. , Wenzhou 325025, China;

[2]Zhejiang Design Institute of water conservancy & Hydro-electric power, Hangzhou 310002, China;

[3]Zhejiang Guangchuan Engineering Consultation Co. , Ltd. , Hangzhou 310020, China

Abstract. The closure of the reclamation project generally requires that the sluice has been built and can be normally opened and closed for drainage. There is a large amount of follow-up work after closured of this project. In order to reach the safe flood control standard for the next typhoon season after the closure, reduce the flood control risk, and strive for sufficient time for the subsequent construction of the seawall, it is necessary to closure in advance under the condition that the sluice has not yet been opened. Therefore, this project demonstrated the feasibility of the closure with cofferdam based on the premise of think outside the box and theoretical calculation. The successful completion and acceptance of the reclamation project proved that the project is successful.

1 Preface

The reclamation project is an important part of the infrastructure to resist storm surge and flood control and moisture-proof engineering system in coastal areas such as Zhejiang, Seawalls can effectively reduce the hazards and losses caused by natural disasters such as typhoons, rainstorms and tides, and provide an important guarantee for the safety of people's lives and property [1]. The key link of seawall construction is "closure" , which determines the success or failure of the whole reclamation project. Therefore, the design and construction of closure gap is the top priority. The closure of the reclamation project generally requires that the sluice has been built and can be normally opened and closed for drainage to ensure waterlogging prevention in fenced areas[2].

This project is a large-scale reclamation project with long dike lines, deep coating surface, complex geological conditions and large wind and waves in the open sea. The outer protective surface of the seawall should be completed as far as possible before typhoon season in order to meet the safety flood control standards and reduce risk. In order to make the seawall settlement occur as early as possible and make the post-construction settlement as small as possible, and meanwhile to bought more time for the subsequent construction of the seawall, On the premise of mature conditions, proposed of " Closure With Cofferdam " innovatively through theoretical calculation, before the sluice has not yet been plugged in advance, ensured the smooth completion of the project, and also bought more time for the subsequent construction of the project .

2 Project summary

A reclamation project is a I grade project, the main building seawall and sluice are I grade buildings. The reclamation area is 66,400 mu, including 20. 33km seawall, divided into the north dike and the north section of the east dike; north 1# sluice , north 2# sluice and navigation hole, east 1# sluice , the total net width of the sluice is 168m; 1# partition dike, 2# partition dike, etc. The 100-year tide level is 5. 44m. The foundation of the seawall is mainly silt and silty soil from 30 m to shallow, especially the III_0 layer and the surface layer of 0. 5m~0. 8m is newly deposited drift mud, and the engineering geological conditions are extremely poor.

3 Calculation of water level in the enclosure area with cofferdam

3.1 Basic information of closure gap

The construction of this Cofferdam is the closure gap of 1# and 2# enclosure area, where the area of 1# enclosure area is 35,700 mu and the average bottom elevation is about -1. 50m; the area of 2# enclosure area is 30,700 mu and the average bottom elevation is about -1. 40m. The flood control standard of the closure gap is 4. 79m and its typical tide type during the 20-year high tide, and the standard of the closure is 4. 02m during the non-flood 10-

* Corresponding author: zjggc2007@163.com

year high tide and its typical tide type. According to the principle of water balance in and out of the inner harbor, the maximum flow velocity is 4. 38m/s at the width of 1000m for 1# closure gap and 4. 38m/s at the width of 900m for 2# closure gap.

3.2 Model calculation and analysis

3.2.1 Calculation method

The model calculation method adopts the non-constant flow of the river network, and the set of partial differential equations for the non-constant flow of the St. Venant nullah is transformed into differential equations by the implicit difference method, and then constitutes a large set of nonlinear equations with boundary conditions and initial conditions, which is solved by Newton iteration and Gaussian column principal elimination method to derive the water level and flow process at each calculation section. The basic equations Saint Venant set of partial differential equations are:

$$B\frac{\partial z}{\partial t}+\frac{\partial Q}{\partial s}=q \qquad (1)$$

$$\frac{1}{g}\frac{\partial v}{\partial t}+\frac{\partial}{\partial s}\left(z+\frac{v^2}{2g}\right)+\frac{Q|Q|}{F^2K^2}=0 \qquad (2)$$

Style (1), (2) in: Z, Q, F, V and K are expressed at a certain moment t and in a certain spatial location S section of the water level, flow, the corresponding overwater cross-sectional area, section average velocity and flow modulus; q for the unit river length side inlet flow.

3.2.2 Design Boundary Conditions

The design upper boundary of Rui'an City is taken to the sail swim of Wenruitang River, Longwan District is taken to the downstream of Tianhe East Reservoir, Tianzhuji Reservoir, Shuangao Reservoir, Yao Xi Reservoir, etc. , using the flow process. Design lower boundary taken to Ou River, Feiyun River and eastward discharge to the East China Sea exit gate, using the water level process.

Calculated initial value: Longwan District planning river normal storage level 2. 6m, planning ground elevation 4. 50m; Rui'an City planning river normal storage level 2. 6m, planning ground elevation 4. 00m ~ 4. 50m.

3.2.3 THE design of 2# enclosure area closure and calculation results

According to the analysis of local hydro tidal conditions and project progress, the time of closuring in 2# enclosure area was chosen on December 22, 2016, and the planned completion and opening of East 1# sluice was at the end of March 2017, so during the period of closuring in 2# enclosure area and completion and opening of East 1# sluice , the weir of East 1# gate was not demolished, and the 1# dike between 1# and 2# enclosure area was not opened, so as to analyze the impact of the discharge and non-discharge of flood water in Longwan II on the water level in the 2# enclosure area and the impact on the discharge of flood water in the upstream Longwan II and Wenrui Plain. 2# enclosure area during the closure of the closure gap is shown in Figure 1.

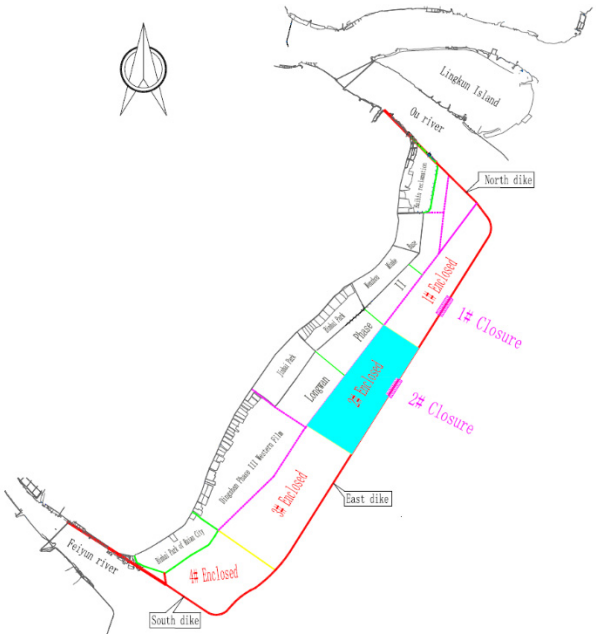

Figure 1. Schematic diagram of closure gap in 2# enclosure area during closure

(1) during the period of closuring in 2# enclosure area, Longwan II 3 # enclosure area and 4 # enclosure area flooding water does not enter oufei 2 # enclosure area, 2 # enclosure area closued on December 22, 2016, the starting water level within the enclosure area is tentatively set at 0. 50m, to the end of March 2017 East 1 # sluice water opening, 2 # enclosure area water level within the raised about 0. 1m to 0. 6m. If a rainfall of 5-year magnitude is encountered during the period, the water level in the 2# enclosed area will be raised by about 0. 44m to 0. 94m.

(2) during the period of closuring in 2# enclosure area, Longwan II 3 # enclosure area and 4 # enclosure area flooding water enter oufei 2 # enclosure area, 2 # enclosure area closued on December 22, 2016, the starting water level within the enclosure area is tentatively set at 0. 50m, to the end of March 2017 East 1 # sluice water opening, 2 # enclosure area water level within the raised about 0. 17m to 0. 67m. If a rainfall of 5-year magnitude is encountered during the period, the water level in the 2# enclosed area will be raised by about 0. 79m to 1. 29m.

(3) during the period of closuring in 2# enclosure area, considering Longwan District water system connected with Longwan II 3# enclosure area and 4# enclosure area, part of its waterlogged water into oufei 2# enclosure area, 2 # enclosure area closued on December 22, 2016, the starting water level within the enclosure area is tentatively set at 0. 50m, to the end of March 2017 East 1 # sluice

water opening, If a super standard flood is encountered during the period, the water level within the 2# enclosed area exceeds 2. 6m. To ensure the safety of flood control and drainage in Longwan District of Wenrui Plain and Rui'an City, open the 1# partition dike between 1# and 2# enclosure area, and bury 10 culverts of 1m diameter in the lower part of the coating surface, i. e. the area near Ou Fei East seawall, to communicate the waters between 1# enclosure area and 2# enclosure area, so that the flooded water in the enclosure area will be discharged outwardly through the d closure gap of 1# enclosed area.

3.2.4 THE design of 1# enclosure area closure and calculation results

According to the analysis of local hydro tidal conditions, engineering progress, etc. , the time of closuring in 2# enclosure area was chosen on March 7, 2017, until the 2017 typhoon season, the North 1# sluice and North 2# sluice cofferdam will not be demolished, 1# partition dike between 1# and 2# enclosure area will not be opened, considering that East 1# sluice of 2# enclosure area gate is completed and open to water, the flood water of Longwan II can be discharged into the East China Sea through 2# enclosure area via East 1# sluice , not into 1# enclosure area. analysis of the possible water level impact within the 1# enclosure area. 1# enclosure area closure gap during the closure of the schematic diagram is shown in Figure 2.

(1) during the period of closuring in 1# enclosure area, considering the completion and opening of East 1# sluice of 2# enclosure area, the flood water of Longwan II can be discharged into East China Sea through East 1# sluice of 2# enclosure area and not into 1# enclosure area, 1# enclosure area closured on March 7, 2017, the starting water level in the enclosure area is tentatively set at 0. 50m, and the water level in 1# enclosure area will be raised by about 0. 31m to 0. 81m before the 2017 flood season. If a 5-year rainfall is encountered during the flood season, the water level in the 1# enclosure area will be raised by 0. 66m to 1. 16m.

(2) If during the period encountered super standard flood, 1 # enclosed area water level exceeds 2. 6m, in order to ensure the safety of flood control and drainage in Longwan District of Wenrui Plain and Rui'an City, open the 1# partition dike between 1# and 2# enclosure area, and bury 10 culverts of 1m diameter in the lower part of the coating surface, i. e. the area near Ou Fei East seawall, to communicate the waters between 1# enclosure area and 2# enclosure area, so that the flooded water in the enclosure area will be discharged outwardly through the d closure gap of 1# enclosed area.

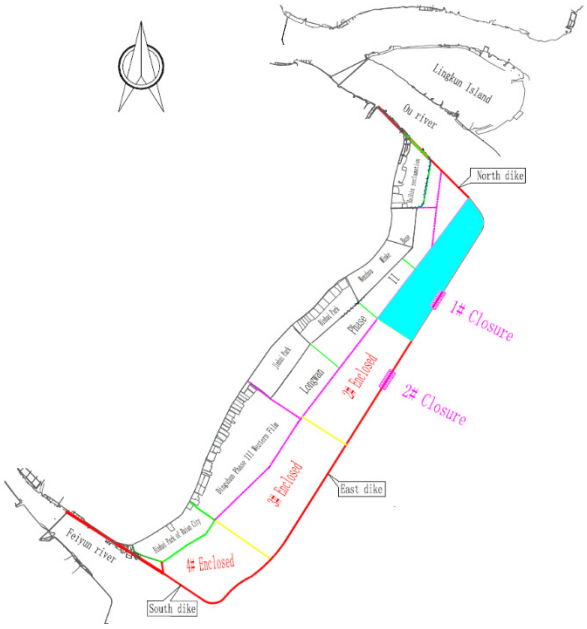

Figure 2. Schematic diagram of closure gap in 1# enclosure area during closure

3.2.5 Analysis of calculation results

Condition 1: Ou Fei 1# and 2# enclosed area is not closured, affected by the outer sea tide level, the 20-year flood water level within the enclosed area is 2. 53m ~ 3. 01m.

Condition 2: When the 2# enclosed area is closured, and the East 1# sluice is not open to water, on the one hand, it can not be affected by the tide level, on the other hand, Longwan II and Wenrui plain part of the flooded water can use the storage volume of the 2# enclosed area, so the water level of Tianhe, Sanjia, East Gate and Field Bridge is slightly reduced, and the flooded water level in the 1# and 2# enclosed area is slightly raised, and the raised range is 0. 04m ~ 0. 07m.

Condition 3: 1# enclosed area is closured, consider Longwan and upstream flood water does not enter 1# enclosed area, on the one hand through the East 1# gate discharge into the East China Sea, on the other hand can make full use of 2# enclosed area storage volume, the upstream Tianhe, Sanjia, East Gate, field bridge water level reduced 0. 01 ~ 0. 11m, 2# enclosed area through the East 1# sluice tide discharge, can reduce the highest water level of 2# enclosed area 0. 31m, Because 1# enclosed area does not bear the influence of the upper tourist water and tide, the water level in the enclosed area is reduced significantly.

Condition 4: On the basis of Condition 3, considering that 1# enclosed area bears part of the upstream flooding, the water level of the upstream Tianhe, Sanjia, Dongmen and Field Bridge can be further reduced by 0. 01m~0. 05m, the flooding water level of 2# enclosed area an be reduced by 0. 31m, and the water level of 1# enclosed area is raised by 1. 22m because it bears part of the upstream flooding.

In summary analysis, although sluice of the 1 # and 2 # enclosure area has not yet been opened to water (cofferdam still exists), the early stage only by 1 # closure gap, later by the East 1 # sluice drainage, theoretically

can also meet the entire perimeter water level control requirements.

4 Emergency preparedness

If the period encounters super standard flood, the water level within the 1# enclosure area exceeds 2. 60m, in order to ensure the flood control and drainage safety of Longwan District of Wenrui Plain and Rui'an City, on the basis of 10 culverts of 1m diameter buried in the 1# partition dike, further excavate the 1# and 2# enclosure area between the 1# partition dike to -1. 00m elevation, and determine the width of excavation according to the strength of super standard flood, so that The flood water of the 1# and 2# enclosure area is discharged through the East 1# sluice to meet the drainage requirements of the whole area. Through the development of the above emergency plan, the subsequent construction of the project after the closure of the plug will provide more adequate protection.

5 Program implementation results

The 2# closure gap started to closured in October 2016 and was successfully closured in December 2016, and the East 1# sluice was opened to water in April 2017; the 1# closure gap started to closured in December 2016 and was successfully closured in March 2017, and the North 1# sluice and North 2# sluice were opened to water in July 2018. During the implementation of the program, the smooth progress of the project was ensured through water level monitoring in the perimeter area as well as contingency plans, and the main project was successfully completed and passed the acceptance in June 2019. The program with closure with cofferdam has advanced the construction period of this project by 12 months.

6 Conclusion

Usually, the reclamation project requires that the sluice has been completed and can be opened and closed normally for drainage before closuring. Due to the special nature of this large scale reclamation project, it is necessary to closured in advance. Therefore, this project broke through the conventional thinking and demonstrated the feasibility of the scheme of closure with cofferdam through theoretical calculations. During the implementation of the scheme, the water level monitoring in the polder area and the emergency plan ensured the smooth progress of the project. The successful completion of the polder project proved the success of the scheme and provided a favorable reference for the subsequent reclamation projects.

References

1. Huang Jinlin, Jiang Wei. Technical Supervision In Water Resoures,03，1-3，(2009).
2. Reclamation Bureau of Water Resources Department of Zhejiang Province. Hangzhou： Reclamation Bureau of Water Resources Department of Zhejiang Province，(2010).
3. Yuan Wenxi, Wu Lei, Xu Ji, et al. . Hangzhou： Zhejiang Design Institute Of Water Conservancy And Hydro-Electric Power ,(2012).
4. Yuan Wenxi, Wu Lei, Xu Ji, et al. S. Hangzhou： Zhejiang Design Institute Of Water Conservancy And Hydro-Electric Power ,(2014).
5. Chen Dechun, Wu Jiwei, Li Yu, et al. Study on closure technique for sea reclamation works[J]. Journal of Hohai University(Natural Sciences), 2002(5) : 67-70.