Three-dimensional Hydrodynamic Analysis of Yushan Petrochemical Reclamation

Yu Gao\textsuperscript{b*}, Liang Duo Shen\textsuperscript{b*}, Yi Chun Ding\textsuperscript{c*}.

\textsuperscript{1}Zhejiang Ocean University, Zhoushan 316000;
\textsuperscript{2}Zhoushan Port and Shipping Engineering Planning and Design Institute Co.Ltd, Zhoushan 316000

\textsuperscript{a*}3306610257@qq.com, \textsuperscript{b*}slduo@zjou.edu.cn, \textsuperscript{c*vpsbox@163.com}

Abstract. With the help of Mike 3 software, a three-dimensional hydrodynamic mathematical model was built for Daxiaoshan sea area. The model was calibrated and verified by the measured tidal current and tidal level data. The influence of Daxiaoshan reclamation project on the surrounding hydrodynamic conditions was analyzed by the numerical simulation of tidal current. The results show that in the model verification, the tide level only has a little deviation in the neap tide stage, and the velocity error is controlled within 0.4m/s. The influence of reclamation projects is mainly concentrated in the vicinity of reclamation areas and has no influence on the hydrodynamic conditions in a large area of sea. The three-dimensional effect of the positions of the southeast and southwest dikes is obvious, and the vertical velocity distribution of the south dike is the most uneven because of the complex terrain conditions. Using the Mike 3 hydrodynamic module can better simulate the flow field distribution in the engineering area and the surrounding sea area of the project, and can better guide the construction of related projects.

1. Introduction

As an important way of coastal development, reclamation is of great significance to the economic development of coastal countries and regions. In order to avoid the damage of reclamation to the original Marine dynamics and ecological structure, it is necessary to study the impact of reclamation project implementation on the surrounding Marine environment. Many scholars at home and abroad have done similar related studies by using numerical simulation, most of which are based on two-dimensional hydrodynamic model. Gu Jie\textsuperscript{[1]} established a two-dimensional tidal current mathematical model to analyze the influence of nanhui East Shoal silting promotion Circle project on the south trough, north trough and transverse sediment channel of the Yangtze Estuary. Zhang Yuqian\textsuperscript{[2]} established a plane two-dimensional flow and sediment model based on Mike 21 software, and verified that the model could be used to predict the maximum scour depth of rivers in practical engineering. Duan Xiaolan\textsuperscript{[3]} established a two-dimensional model to analyze the hydrodynamic changes before and after zhubaming ecological water conservancy project. Deng Xinchao\textsuperscript{[4]} established a two-dimensional hydrodynamic model of changing-Huangshan Railway crossing Jinjong River based on Mike 21 software to provide a basis for flood control evaluation. Deng Xinchao\textsuperscript{[5]} studied and analyzed the application of Mike 21 model in flood control evaluation of bridge engineering. However, two-dimensional models can only simulate the average flow field distribution and cannot simulate the flow velocity in the vertical stratification direction. Meanwhile, there are relatively few studies on the three-dimensional hydrodynamic force in a certain region. Zhang Xiaolei\textsuperscript{[6]} established the Xiaolangdi Three-dimensional water-sediment mathematical model to study and analyze the water-sediment movement of the dam. Zhou Zhengqiao\textsuperscript{[7]}
reasonably evaluated the water exchange capacity of Fangcheng Bay in the dry season by establishing the Mike 3 hydrodynamic numerical model. Liu Jiang [8] established a three-dimensional hydrodynamic model to simulate the hydrodynamic field variation process of Saiimu Lake based on the topography and hydrological conditions of the lake.

Zhoushan green petrochemical base project is located in the Zhoushan Islands, daishan daishan west of the sea area, daishan, Xiaoyu mountain plan to form 40 million tons of large refining area through reclamation into land, mainly related to oil products refining, at the same time for supporting the extraction and drainage and wharf construction and other sea-related projects. In view of the characteristics of interisland watercourses in the surrounding islands of this project, it is difficult to reflect the flow field around it clearly by two-dimensional hydrodynamic force, so a three-dimensional model is adopted to carry out a relatively systematic study on this area. This article Mike 3 model was used to simulate the Zhoushan big fish reclamation project in the island's influence on the hydrodynamic conditions around, before and after the analysis of the engineering reclamation district and near the area off the coast of the flow field distribution, the engineering surrounding seas has carried on the detailed study of the change of hydrodynamic characteristics, and put forward reasonable reclamation on the basis of the construction scheme, provide guarantee for the long-term development.

2. Three dimensional hydrodynamic model

2.1 The governing equation

The mathematical basis of the Mike 3 model is the Reynolds averaging N-S equation, which includes the effects of turbulence as well as density changes. The main governing equation of Mike 3 hydrodynamic model [9] is:

Flow continuity equation:

\[
\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = S
\]

The N-S equation of horizontal momentum in the X and Y directions:

\[
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} = f v - g \frac{\partial h}{\partial x} + \frac{1}{\rho} \frac{\partial p}{\partial x} - \frac{g}{h} \left( \frac{\partial s_{xx}}{\partial x} + \frac{\partial s_{xy}}{\partial y} \right) + F_{u} + \frac{\partial (\frac{\partial u}{\partial x})}{\partial x} + F_{s}
\]

Where \( t \) is time, \( x, y \) and \( z \) are the eastern, northern and vertical coordinate axes in cartesian coordinate system; \( \eta \) as the water level; \( d \) is for water depth; \( h=\eta+d \) is the total water depth; \( u, v, w \) are the velocity components in the \( x, y, \) and \( z \) directions; \( f=2\Omega\sin\phi \) is the Coriolis force parameter (\( \Omega \) is the rotation Angle, \( \phi \) is the geographical latitude); \( g \) is the acceleration of gravity; \( \rho \) is the density of water; \( s_{xx} \), \( s_{xy} \), \( s_{yx} \), \( s_{yy} \) is the radiation stress tensor; \( v_{t} \) is the vertical turbulent (or eddy current) viscosity; \( p \) is atmospheric pressure; \( S \) is the point source emission; \( \langle u_{a}, v_{s} \rangle \) is the rate at which the point source is discharged into the surrounding water.

2.2 The boundary conditions

The open boundary of the model is controlled by water level, that is, the open boundary condition is obtained by the method of tidal level forecast. According to the harmonic constant of 16 main tidal components (M2, S2, N2, K2, K1, O1, P1, Q1, MU2, NU2, T2, L2, N2, J1, M1 and 001), the open boundary tidal level is calculated by the prediction formula of the open boundary tidal level:

\[
\zeta = A_{v} + \sum_{i=1}^{11} H_{i} F_{i} \cos[\pi_{i}(t - (t_{0} + u)) + g_{i}]
\]

(4)
A_0Is mean sea level,F_1 (v_0 + u_1) Is astronomical element,H_1, g_1,Is the harmonic constant.In the closed boundary, the normal derivative of the velocity is zero, and in the tidal flat, the flood flat boundary is adopted. Model calculation step length according to CFL condition for dynamic adjustment, to ensure stable model calculation, the average time step 2 s, shortest time step is 0.01 s. Because the calculation model is large, Coriolis force should be considered. According to the calculation formula, it varies with the geographical latitude of the calculated sea area.

3. Model validation

3.1 Model areas and grids

Scope model than project can influence scope, covering the entire hangzhou bay and part of the east China sea, the Yangtze river estuary, take in the fashion world vertex jiangyin Yangtze river upstream boundary, hangzhou upstream boundary in China pu tide level station accessories, computing area is located in east longitude 120 ° ~ 126 °, zhoushan sea area and engineering local terrain as shown in figure 1. The computational domain, the unstructured triangular grid subdivision adjustment control grid density and grid scale minimum of 20 meters, can better describe project front underwater topography and coastline, ensure sufficient accuracy, in engineering area, away from the grid is relatively sparse, by setting the realize smooth transition between different scales grid, a total of 41041 nodes, 78473 units.

3.2 Tidal level and current verification

In this model validation, the measured tidal current data of the third Shipping Engineering Survey and Design Institute Co, Ltd. during the hydrological test period were adopted. Among them, the tidal level of the temporary measurement station T5 and Luchao Port were verified by small and large tides (the time of tidal tide measurement was from May 4, 2015 to May 5, 2015; The duration of the mesotidal current measurement was from May 7, 2015 to May 8, 2015. Neap current measurement from May 12, 2015 to May 13, 2015); Similarly, flow verification was performed on the surface and bottom flow velocity data of the fixed-point observation stations N2, N6 and N12 from May 4 to May 5, 2015. The coordinates of the observation stations are shown in Table 1.

| Points      | X (m)     | WGS84 coordinates (L_0=123°) | Y (m)  |
|-------------|-----------|-------------------------------|--------|
| T5          | 417841.2763 | 3381620                       |        |
| luchaoang   | 388425.6851 | 3411710                       |        |
| N2          | 403722.0698 | 3390000                       |        |
| N6          | 404497.8488 | 3380000                       |        |
| N12         | 417958.2732 | 3390000                       |        |

Figure 2 shows the tide level verification results of T5 and Luchao Port tide station. From the verification, the calculated tide level process is in good agreement with the measured data. FIG. 3 and FIG. 4 respectively show the results of the surface and bottom flow direction verification curves of the three tide stations. The results show that: Three station a tide stations calculated values and measured
values are basic, only N6, N12 surface velocity of individual points vary slightly, may be measurement error or the measured rainfall weather appear from time to tome, this suggests that the 3 d model precision analysis result is good, we through 3 d model for the simulation of tide and validation is feasible.

4. Analysis of tidal current field before and after engineering

4.1 Comparative analysis of average flow field after engineering
In this paper, the surrounding sea area and the local area of the project (south of Yushan Island) are
selected to make a comparative analysis of the average flow field on the two-dimensional model when the spring tide is rising and falling rapidly in the same period. The simulation data can reflect the full cycle of the tidal field in the sea area near the project and the local sea area. Figure 5 shows the engineering surrounding seas before and after the tide tide of sharp contrast, figure 6 shows the fish mountain island south sea tide up nasty tidal current field before and after comparison, the results show that the reclamation engineering, the implementation of the shoreline and trend direction is parallel to the state, make the flow field distribution of the fish near mountain island becomes relatively moderate, slow flow pattern under the whole range. Considering the influence of the corner of the shoreline on the current movement, the change of the southern side of Yushan Island is more obvious in the local area of the project, and the tidal current on both sides of the west and southeast dike is significantly deflected, and the velocity decreases significantly, especially at the dike corners at both ends of the southeast dike. Therefore, this paper will focus on and analyze the flow field in this area.

Fig.5 Comparison of tide field before and after tidal surge in the surrounding sea area
Fig.6 Comparison of tidal current field before and after spring tide rise in local sea area of the project

4.2 Cross-sectional analysis before and after the project
Section 4.1 presents the before and after engineering construction engineering surrounding seas and local sea tide of sharp contrast, the comparison results is the average flow field of a contrast analysis, results show that the flow field in the fish mountain island south ocean change is more obvious, so we focus on the area, in order to better research results. In addition, a relatively flat offshore area was selected for comparison. Figure 7 shows the location of the specific cross section.

Fig.7 Project area and part of the offshore area cross-section location
Figure 8 shows the before and after the project area off the coast of three-dimensional hydrodynamic results, by the cross-sectional view analysis: in relatively flat terrain off part of the cross sectional drawing, the velocity of each layer is evenly distributed along the depth, so we use the 3 d model and the two-dimensional model analysis results of the average of the cross section is about the same, the difference is not very big.
For engineering areas with uneven velocity distribution, three-dimensional models are needed to analyze the vertical velocity of each layer. The results are shown in Figure 9:
In general, through the comparative analysis of the flow field diagram before and after the project and the cross section flow field diagram in the figure above, it can be concluded that: Reclamation engineering implementation, leading to change velocity of the flow field distribution of the engineering area, among them, fish south near the volcanic islands in the island for the southern dike for engineering part of the velocity distribution is more apparent, in part because of the effects of reclamation engineering implementation, and the main reason is that the part of the complex terrain conditions, caused by the inhomogeneity of the terrain around the change of hydrodynamic condition, Therefore, we established a three-dimensional hydrodynamic model to better study and analyze the surrounding flow field. On the other hand, in the open area on the right side of the sea, the terrain is relatively flat, and the velocity in the cross section is evenly distributed along the vertical line. In fact, the calculation results of the three dimensional model and the two dimensional model analysis in this area are similar, with little difference.

5. Conclusion
By Mike hydrodynamic module of zhoushan green petrochemical base 3 phase ii engineering reclamation area numerical model is established, the project construction coast hydrodynamic environmental impact was studied before and after the analysis, the following conclusions: (1) before and after the project construction, the surrounding waters flood presents the flow from southeast to northwest, the local tide movement of the project is basically reciprocating flow, and it is basically reciprocating flow along the direction of parallel shoreline. Due to the influence of many islands, the reciprocating current characteristics are not obvious. The characteristics of rotating flow in the west dike, southeast dike and south dike front are obvious. (2) After the project, the outboard sea area of the embankment and the corner area of the embankment have the flow. The construction of the embankment results in the concentration of water outside the embankment. The narrow stream beam increases the flow velocity, especially in the south of Yushan Island. (3) Reclamation makes the flow field distribution in the southern dike area of the project change the most, and the three-dimensional effect is the most obvious. Among them, the closer the south dike area is to the surface, the greater the velocity, while in the whole south sea of Yushan Island, due to the complicated terrain conditions, the vertical velocity distribution near the south dike area is more uneven. In the far open sea area near the right side with relatively flat terrain, the velocity is evenly distributed along the vertical line, and the THREE-DIMENSIONAL effect is not obvious.
Fund project: 
the national natural science foundation of China (51879237), technology bureau general project (2019 c21026), zhoushan city, zhejiang province, no.12, general scientific research project (Y201839488)

References
[1] Gu Jie, Zheng Yuhua. Nanhui dongtan enclosure engineering numerical simulation analysis of the impact of Yangtze river regime [J]. Journal of Marine science, 2017, 9 (01) : 65-75.
[2] Zhang Yuqian. Two-dimensional water-sediment model based on MIKE 21 research and application [J]. Journal of sichuan building, 2021 9 (01) : 177-179 +185.
[3] section of xiaolan, Han Shuai, Luo Chunjun, wang xy. Hydrodynamic Numerical Simulation of Baojing Bambooping Ecological Water Conservancy Project based on MIKE21 [J]. Hunan province water conservancy and hydropower, 2020 (02) : 21-25.
[4] wang. Skew bridge based on two-dimensional hydrodynamic model of flood control impact study [J]. Journal of harnessing the huaihe river, 2021 (04) : 18-20.
[5] new super deng. Application of Mike21FM and SMS software in Numerical Simulation of Flood Control Evaluation of mechanical loading expressway Bridge Engineering [J]. Water conservancy and technical supervision, 2021 (3) : 41-45.
[6] Zhang Xiaolei, xin-yu wu, Wang En. MIKE3 application of water and sediment in the xiaolangdi dam simulation [J]. Journal of north China water conservancy and hydropower university (natural science edition), 2018, 33 (3) 6:73-78.
[7] weeks for bridge, xabi, Qiu Wenbo, guan-yu li. Based on the abundant water season MIKE3 fangcheng bay water exchange capacity study [J]. Journal of guangxi science, 2020, 27 (3) : 311-318.
[8] liu jiang, Hu Yunling, ginger, Cheng Yan. SaiLiMu MIKE3 software was used to study the wind field on the influence of water dynamic field [J]. Journal of environmental protection in xinjiang, 2015, 5 (4) : 29-33.
[9] li na, an-gang Lou, xue-qing zhang, burden of proof, the king Xu Kun. Journal of Oceanology and Limnology,2019(02):1-9. (in Chinese)