*Proceedings of the 7th International Conference on Asian and Pacific Coasts (APAC 2013) Bali, Indonesia, September 24-26, 2013*

# THE PREDICTION OF THE EFFECT OF OCEAN ENGINEERING ON JINTANG TIDAL CHANNEL EVOLUTION

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ABSTRACT: Tidal channel is the most important waterway of harbor in coastal area, Jintang tidal channel is a natural tidal passage and waterway of Ningbor Port in the south-east side of Hangzhou Bay,. It is an important passage for tide passing in and out in Hangzhou Bay too. There has been a continuous shoals reclamation in the west side of it because of the demand for land and other ocean engineering such as port and bridge recently, this is potential threaten to the channel. With investigation, shore evolution, dynamic analysis, numerical simulation and model prediction, This paper gives a research for the evolution of Jintang channel, the variation of dynamic induced by different reclamation and ocean engineering, and builds a prediction model using equilibrium theory of dynamic and water depth adaption in channel, it shows that the runoff will be reduced and the sea bed will be adjusted suitably after reclamation and related adjacent human activities around the channel.

Keywords: Tidal channel, erosion and deposition, coastal engineering, evolution, numerical model.

## BACKGROUND

Tidal channel is a passage where waters surrounded by land such as tidal coasts, bays, lagoons exchange waters with the open sea, tidal current is the main driving force to maintain its depth(Ren M.E. et al.1982) Jintang channel is located at the south side of the mouth of Hangzhou bay, it extends from west to east, it is the natural tidal channel of the north side of Chuanshan peninsula, is the channel connecting Hangzhou bay and the open sea, and is the important channel of the south side of Hangzhou bay to transport tidal current and sediment. It is of 3-6km in width, about 10km in length, its north side is Jintang island, the water of the bedrock is deep, its south side is silty coast, there are deep grooves along the coast. The maximum water depth of Jintang channel is more than 80m, water gradually becomes shallow from outside the Qili island.

The power of tidal current in Hangzhou bay is strong, the tidal range and velocity is large, the strong power of tidal current maintains the depth of deep grooves in Jintang channel, -10m isobath (theoretical datum) is close to the south coast, all of this provides an excellent environment for port construction, and this is rare in China coast. Figure 1 is a Satellite images of Jintang channel and its nearby, the Figure 2 is the map of Jintang channel in water in water depth

Ningbo , the city in Zhejiang province, located at the south bank of Hangzhou bay, is in a shortage of land resources. It has reclaimed totally more than 70km$^2$ of the sea through Hangzhou bay from the 1950s, its boundary stretched more than 4km to the sea at the biggest inning; at the same time, many great cross-sea bridges were built in the project of connecting islands in

Zhejiang province, Jintang bridge is just one of them, it is just located at the west mouth of Jintang channel, and the bridge restrict the ebb power of Jintang channel (Huang S. C. et al.2005),enlarge much more resistance to water movement in Jintang Channel.


Fig.1 Satellite remote sensing image of Jintang channel and its surrounding

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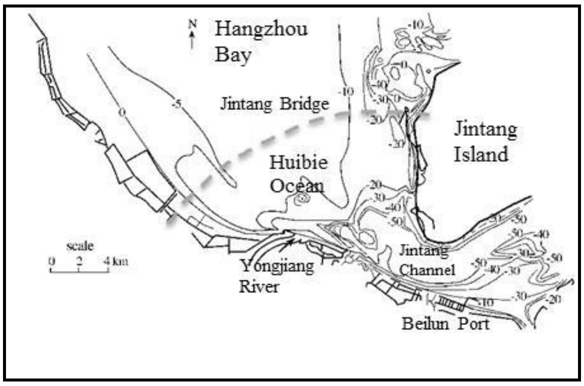


Fig.2 Underwater topography of Jintang channel

Ningbo port is the second largest port in China, and Jintang channel is the most important waterway, it works to make sea lanes from Ningbo, Zhoushan in Zhejiang province can sail smooth . Figure 1 is the satellite remote sensing image of the geographical situation of Jintang channel and its surroundings, during the past 30 years, this area has carried out a series of coastal engineering construction, such as the inning of Andong riffle, the construction of Zhenhai port , Jintang bridge, and Beilun port, due to these coastal engineerings, the coastline stretch to the sea, the boundary condition of Jintang channel changes, thus the tide volume is cut off at a certain extent, this makes it hard to maintain the water depth of the deep grooves.

It should keep eyes on the impacts of the construction of great important coastal engineerings on natural tidal channels , because it is of great significance to reduce the influence of human beings, to plan the construction of coastal engineerings in order to reduce their impacts on Jintang channel, and to ensure to protect the normal navigation of deep water channels.

## FEATURES OF WATER, SEDIMENT AND THE EVOLUTION

### Characteristics of Tides and Currents

Tidal wave in the sea firstly flows into Luotou channel via Fodu gate, Fuli gate, Xiashi gate, Fodu channel and Pushen channel, and then it flows into Jintang channel via Cezi channel and Chuanshan channel. Waves in the open sea are progressive waves, when they enter into the channels, they turn into the mixed tidal waves of standing waves and progressive waves because of the effects of topography.

Average tidal range gradually decreases from Shenjiamen to the west, and reaches a minimum near the area from Beilun to Yongjiangkou, further west, it shows an increasing trend.

Table 1 The average tidal range of each station along the channel from east to west (unit:m)(Jing,G.X.,et al.,1989)

| Station | Shenjia-men | Zhuwan | Yadan-mountain | Daxie | Maojiao | Beilun | Zhenh-ai | Dapu-kou | Haihua-ngshan |
|---|---|---|---|---|---|---|---|---|---|
| Average tidal range | 2.43 | 2.06 | 1.88 | 1.87 | 1.71 | 1.71 | 1.75 | 1.86 | 2.52 |

### Movement Characteristics of Currents

Flood tide of Jintang channel is mainly affected by two strands of flood tide, one comes from Chuanshan channel, the other comes from Cezi channel which pass by the north side of Daxie island, after joining into Jintang channel, the two strands of flood tide then flow into Huibie ocean and Hangzhou bay via Yongjiangkou-Dapukou section; part of the ebb flow in Hangzhou bay flow along the south bank after passing through Andong riffle, and gather into Jintang channel from Huibie ocean, this leads to the NW-SE towards trumpet-shaped topography. Special geomorphic environment accounts for the deep water, swift flow, and complex flow pattern of Jintang channel. Maximum velocity in local places reaches 2.00m/s, current velocity varies among different places. Table 2 shows the distribution of some stations' maximum ebb and flow tide velocity.

Table 2 Velocity of some stations in Jintang channel(unit:m, measured in June 21,2012,from West to East )

| Station | 1# | 2# | 3# | 4# | 6# |
|---|---|---|---|---|---|
| $V_{flood}$ / $V_{ebb}$ | 1.66/1.74 | 1.27/1.93 | 1.56/1.51 | 1.16/1.27 | 0.98/1.43 |

It can be seen in the table that the ebb take the dominant place except the 3# station, but the characteristics of current is not obvious in offshore places and in some places which are affected by the head of cape.

### The Features of Sediment

The movement of tidal current and sediment is a continuous suspension, transport, and deposition progress of sediment driven by current, the long-term effect of continuous resuspension and deposition cause bed erosion and accumulation, and then influence the development and evolution of submarine topography(LI Z H et al. 2005). Sediment movement in Jintang channel is part of that in Hangzhou bay, according to past observations, sediment concentration gradually decreases from Hangzhou bay to the east along Jintang channel, this indicates the characteristics of sediment movement. In Huibie ocean west of Yongjiangkou, the maximum average vertical sediment concentration can be 8.00kg/m$^3$(Huang S. C. et al.2005), more than 3.00 kg/m$^3$ near Yongjiangkou, about 2.00 kg/m$^3$ of Beilun, and about 1.20 kg/m$^3$ of the sea near Daxie island; basically, the sediment concentration during the spring tide is the greatest, next is that during the medium tide, concentration ranks the last during the neap tide sediment , the average vertical sediment concentration of neap tide is usually 0.50 kg/m$^3$. Offshore riffles sediment concentration is greater than that of deep grooves. And it reaches the maximum in winter.

Sediment transport characteristics of Jintang channel is obvious, Huang S.C. et al draw a conclusion by analyze some data that the sediment transport channel is Hangzhou bay-Jintang channel-the open sea during spring tide and medium tide, while the direction is opposite during the neap tide.

The main source of sediment in Jintang channel is Hangzhou bay, near rivers, and riffles, sediment from Hangzhou bay is the main source; viewed from the sediment grain size distribution, the grain size of sea bed material is about 0.01mm, suspended load grain size is 0.006~0.009mm, which is very close to that of bottom substance, this shows the exchange between suspended load and bottom substance.

### Evolution Characteristics of Seabed

In the natural state, take the -10m counter as a symbol, it is slowly silting near Daxie island east of Jintang channel(Lu P.D. et al.2002). Since 1978, silting speed of riffles grow faster with the development of Beilun port, coastline from Yongjiangkou to Daxie are all used, and all coastline become artificial. The pile group area back of the wharf quickly silted, this phenomenon also exists in the wharf apron,the -10m counter shifts to the sea, it shows the evolution of Jintang channel(Zhang,J.S. et al.2007).

## THE SETUP OF NUMERICAL MODEL AND ITS VALIDATION FOR A TWO-DIMENSIONAL TIDAL CURRENT

### The Control Equation of the Two-Dimensional Mathematical Model (ZHANG,J.S.,et al. 2011)

$$\frac{\partial \eta}{\partial t}+\frac{\partial hu}{\partial x}+\frac{\partial hv}{\partial y}=0 \qquad (3\text{-}1)$$

$$\frac{du}{dt}=-g\frac{\partial \eta}{\partial x}+fv-\frac{gn^2\sqrt{u^2+v^2}}{h^{4/3}}u+A_H\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right) \qquad (3\text{-}2)$$

$$\frac{dv}{dt}=-g\frac{\partial \eta}{\partial y}-fu-\frac{gn^2\sqrt{u^2+v^2}}{h^{4/3}}v+A_H\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right) \qquad (3\text{-}3)$$

In the formula, u,v respectively represent the component velocity in the direction of x,y; h is the total water depth; η is the water level where mean sea level is calculated from; f=2ωsinφ is Coriolis force coefficient, among which ω is the rotation angular velocity, φ is the geographic latitude of calculation water area; g is gravity acceleration, n is Manning coefficient, $A_k$ is horizontal turbulent diffusion coefficient.

Boundary condition: including open boundary and fixed boundary

Open boundary: open current boundary given the process line of tidal level and velocity

$$u|_{t=0}=const, v|_{t=0}=const, \zeta|_{t=0}=const$$

In the formula, $u_c$, $v_c$, $\zeta_c$ are all provided by the east china ocean wave model; in which, the open boundary is controlled by observed tidal level, $s_c(x,y,t)$ is determined by the relationship of sediment carrying capacity.

Fixed boundary: using impenetrable condition, namely $V_n=0$, n is the outer normal direction of the boundary.

$$u|_{\Gamma_0}=u_c(t,x,y), v|_{\Gamma_0}=v_c(t,x,y), \zeta_{\Gamma_0}=\zeta_c(t,x,y)$$

### Discrete Method

The numerical discretization method of the model is unstructured finite difference format mentioned by casulli and zanolli, and the following equation is obtained(Zhang J.S. et. al 2011):

$$U_j^{n+1}=G_j^n-\theta g\frac{\Delta t}{\delta_j}\left[\eta_{is(j,2)}^{n+1}-\eta_{is(j,1)}^{n+1}\right] \qquad (3\text{-}4)$$

$$V_j^{n+1}=F_j^n-\theta g\frac{\Delta t}{\delta_j}\left[\eta_{ip(j,2)}^{n+1}-\eta_{ip(j,1)}^{n+1}\right] \qquad (3\text{-}5)$$

$$\eta_i^{n+1}=\eta_i^n-\frac{\theta\Delta t}{P_i}\sum_{l=1}^{side(i)}s_{i,l}l_{jsj}h_{jsj}^nU_{jsj}^{n+1}-\frac{(1-\theta)\Delta t}{P_i}\sum_{l=1}^{side(i)}s_{i,l}l_{jsj}h_{jsj}^nU_{jsj}^n \qquad (3\text{-}6)$$

In the above equations, term G and F are explicit terms of the discretized momentum equation, and they can be obtained by the known of velocity and water level at time n.

It can be got:

$$\eta_i^{n+1} - \frac{g\theta^2 \Delta t^2}{P_i} \sum_{l=1}^{side(i)} \frac{s_{i,l} l_{jsj} h_{jsj}^n}{\delta_{jsj}} \left[ \eta_{is(jsj,2)}^{n+1} - \eta_{is(jsj,1)}^{n+1} \right]$$
$$= \eta_i^n - \frac{(1-\theta)\Delta t}{P_I} \sum_{l=1}^{side(i)} s_{i,l} l_{jsj} U_{jsj}^n h_{jsj}^n - \frac{\theta \Delta t}{P_i} \sum_{l=1}^{side(i)} s_{i,l} l_{jsj} G_{jsj}^n h_{jsj}^n \quad (3\text{-}7)$$

As can be seen, the coefficient matrix of the above equation about η is positive definite and symmetric, so the equation is suitable to be solved by the solutions of the sparse matrix like the Jaccobi conjugate gradient method.

After obtaining the water level at the center of each unit, through the weighted average method, we can obtain the following information by interpolation, using the water level at the center of the concurrent unit.
After getting the water level, we can obtain the normal velocity U and the tangential velocity V by the corresponding momentum equation (3-7) and (3-8).

The project is simulated by the model of a range of Hangzhou Bay.

The model verifies the tides of 8 stations, the velocities and the flow directions along (3-6) verticals separately, and it can simulate the movements of the tide in Hangzhou Bay well(Zhang ,J.S.,et al. 2011)

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$$\eta_{ip}^{n+1} = \frac{\sum_{n=1}^{m} P_{ine(i,j)} \eta_{ine(i,j)}^{n+1}}{\sum_{n=1}^{m} P_{ine(i,j)}}, i = 1, \ldots N_P \quad (3\text{-}8)$$

## FORECAST OF THE COASTAL ENGINEERING PROJECT'S IMPACT ON DEEP GROOVES' EVOLUTION

### Main Coastal Construction Projects

In recent 30 years, lots of reclamation projects have been made in Andong Shoal. Figure 3 shows us some shorelines changed in different colors after several important reclamations in different times. Besides those, there are the constructions of the Jintang Bridge and the port at the south shore of Jintang Channel. Now, the shoreline from the chemical industry region in Zhenhai to the east of Daxie Island has all been constructed to the frontage of ports. According to the study [5], the construction of the Jintang Bridge could have effect on the tidal current in Jintang Channel for about 4%. To make the calculation of the numerical model convenient, we designed 4 kinds of working conditions: the shoreline in 1985 as condition 0; the shoreline in 2005, which is before the reclamation project in the Xinhongkou, as condition 1; the shoreline after the reclamation project in the Xinhongkou as condition 2; the shoreline after the reclamation in the north side of the Xinhongkou as condition 3; the shoreline after the future reclamation as condition 4.

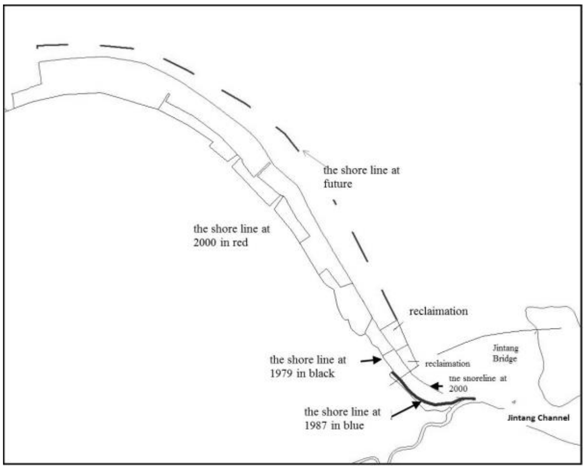


Fig. 3 The shorelines after reclamations in different times

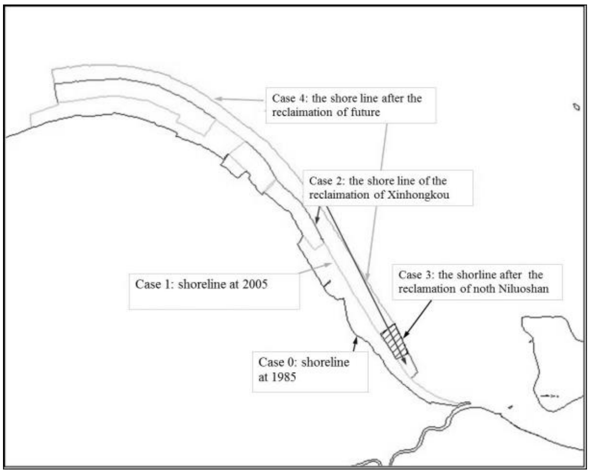


Fig. 4 The cases of the numerical model test

For the convenience of the analysis, it doesn't take the construction of the port at the south shore of Jintang Channel into consideration this time, and this will be included in our next study.

### Forecasting method

The depth of the tidal channel is maintained mainly by the dynamic of the tides in natural. The material factors that caused geomorphic evolution is the sediment development and environment changed. The increase of the dynamic in tidal inlet will cause the suspension of sediments, which will lead to geomorphology scouring, and the decrease of the dynamic will cause the sedimentation of sediments, which will lead to geomorphology deposition in a long term. So establishing a forecasting method that combines dynamic with landscape is an effective way to forecast the evolution of deep groove..

Seabed in nature balance is maintained by the dynamic of the ocean, tidal flow and waves. Generally, waves do damage to the recovery of tides. In tidal inlet area, there are mainly tides, so as the tidal currents changing can make the seabed makes the cyclical adjustment, resulting in the new balance of scouring and silting in a long term. The construction of the project has changed local dynamic environment and sediment environment, which caused a scouring and silting adjustment of the landscape.

Sedimentation caused by the change of tidal current in tidal inlet or channel can be calculated by the following equation [9].

$$P = \frac{K_2 S\omega\, t}{\gamma_0}\left[1 - \frac{V_2}{2V_1}\left(1 + \frac{d_1}{d_2}\right)\right] \qquad (4\text{-}1)$$

This is a calculation formula for port or channel siltation.

In the formula, P is the sedimentation volume in a period of t after the construction; $K_2=0.13$, S is the averaged sediment concentration at local place; $\omega=0.0005$m/s; $\gamma_0=1750d^{0.183}$; $V_1$,$V_2$ are the velocity before and after forecasting respectively; $d_1$,$d_2$ are the depth of the water before and after the project respectively.

When the scouring and silting are in balance, in other words, when it is non-silting and non-scouring, P=0 , there is:

$$\frac{d_1}{d_2} = \frac{(1 + 8q_1/q_2)^{1/2} - 1}{2} \qquad (4\text{-}2)$$

In this formula, $q_1$,$q_2$ are the flow of unit width before and after the project respectively. Use formula (4-1) to calculate the water depth corresponding with the flow of unit width, and the depth is the corresponding water depth when the scouring and deposition is in balance. Hence it is easy to get the scouring and silting intensity at that time.

## RESULTS ANALYSIS AND DISCUSSIONS

The scouring and silting of Jintang Channel is a combined effect of nature evolution and human activities, and it is a response to nature activities. According to the preceding analysis, it mainly shows it's response to the change of hydrodynamic caused by the change of the tidal inlet's boundary condition.

Figure 5 is a vector diagram that shows the flood and ebb tide under different case. It can be seen that under different working conditions, the sections' widths of Huibie Ocean constantly narrow.

The reclamation projects has caused 2 results: one is the change of the flow pattern at the boundary of the reclamation area, but it changes little in the remote area; the second is the change of tidal volume.

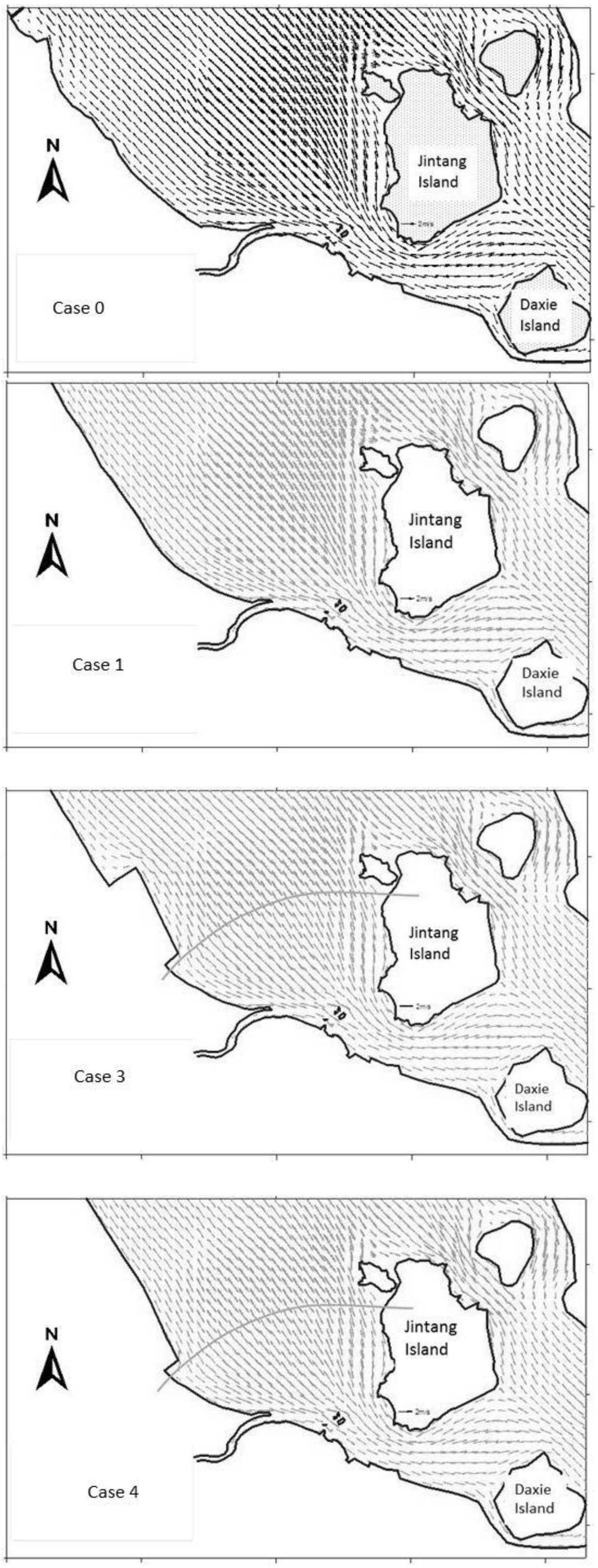


Fig.5. Local flow chart under different cases

The flow usually moves along the path of the shortest in hydraulics, but when the environments change, such as the narrowing of the reclamation area, bridge construction, dams and bank protection projects, the resistance force on fluid increases, which makes the flow change the path. This is particularly obvious in the ocean, and results in reducing of sections' flow, which is quite clear in Jintang Channel. Through an analysis of the sea charts before 2004，Ni Yunlin found out the silting process was a response to the change of the environment(Ni,Y.LI.,et.al, 2012).

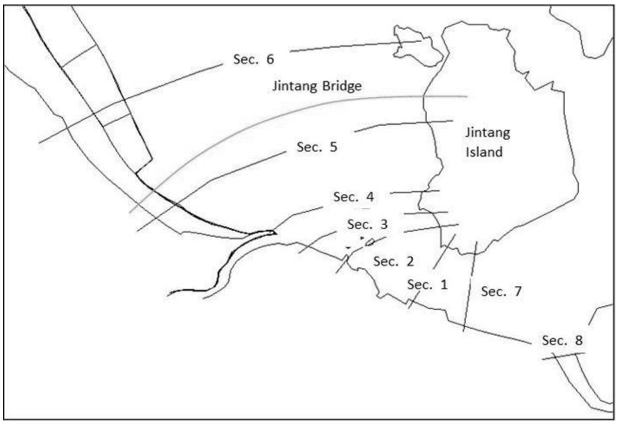


Fig. 6 The map of sections position

In order to compare the change of tidal volume in the channel under different working conditions, 7 sections were selected (see Figure 6) to count the tidal volume during the flood tide and the ebb tide respectively.

$$Q=\iint_{0,0}^{t,L} h(x,y) \times u(x,y)\, dl \times dt$$

In the formula, t is the time of the flood tide and the ebb tide, h(x,y)is the water depth, L is the width of the section.

The runoff in given cross-sections have different reduction corresponds to the cases showed in the Table 4, which indicates that the construction of marine engineering weaken the force of maintaining the waterway of Jingtang Channel. The area of flow section have reduced can be also confirmed by the fact that the maximum volume of tide decreased by 22%, resulting the further adjustment of the depth of the groove and increasing the deposition in the groove.

Depth averaged deposition of different sections are listed in table 4. The maximum of depth of deposition can reach to 3m by the prediction of long-term reclamation. Special attention should pay to the further strengthened trend of siltation with the increasing possibility of the reduction of discharge.

It should be pointed out that this study only focuses on the impact of reclamation and construction of bridge. Considering the superposition of wharf engineering, this effect will be more greater and obvious; Moreover, this paper only study the averaged water depth of the section and can't reflect the distribution of the local erosion-deposition. Further study should be made on the prediction of other factors.

Table 4 The variation rate of tidal runoff in different sections*(%)

| | Section 1 | | Section 2 | | Section 3 | | Section 4 | | Section 5 | | Section 6 | | Section 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FL* | Ebb | Fl | Ebb | FL | Ebb | FL | Ebb | FL | Ebb | FL | Ebb | FL | Ebb |
| Case 1 | -3 | -4 | -4 | -4 | -6 | -3 | -5 | 6 | -6 | -6 | -10 | -6 | -5 | -4 |
| Case 2 | -9 | -8 | -8 | -8 | -11 | -7 | -10 | -11 | -12 | -13 | -17 | -11 | -9 | -7 |
| Case 3 | -9 | -8 | -9 | -9 | -11 | -7 | -10 | -12 | -12 | -14 | -18 | -11 | -10 | -7 |
| Case 4 | -14 | -12 | -13 | -13 | -17 | -11 | -15 | -17 | -18 | -19 | -22 | -13 | -15 | -11 |

*FL is the rate of flood runoff variation, Ebb is the rate of ebb runoff variation before and after the case

Tab.4 The silting thickness in sections after different cases（m）

| Sec. / Case | Section 1 | Section 2 | Section 3 | Section 4 | Section 5 | Section 6 | Section 7 | Section 1 |
|---|---|---|---|---|---|---|---|---|
| Case 1 | 0.60 | 0.70 | 0.80 | 0.70 | 0.20 | 0.10 | 0.60 | 0.30 |
| Case 2 | 2.00 | 1.80 | 1.90 | 1.10 | 0.80 | 0.30 | 1.90 | 1.02 |
| Case 3 | 2.10 | 1.85 | 1.90 | 1.20 | 0.90 | 0.35 | 1.90 | 1.08 |
| Case 4 | 3.00 | 2.50 | 2.97 | 1.60 | 1.10 | 0.45 | 3.00 | 1.30 |

**CONCLUSIONS**

This paper gives an introduction about natural conditions, tide and sediment movement and geomorphological changes analysis and discussion about Jintang channel and its nearby. Based on tidal numerical model, the effects of Andong shoal reclamation and Jintang bridge building are studied, it shows that there is a obvious changes of runoff after large scale reclamation in Andong shoal, It should be taken enough notification because it will result in the channel deposition, and threaten the protection of navigation.

Based on the theory of equilibrium water depth in channel under the function of tidal flow, a prediction model has been setup to predict the water depth change to Jintang channel induced by ocean engineering building such as Andong shoal reclamation and bridges, it shows that different case will make a certain silting in the channel, the biggest can reach to 3 m.

This paper has some insufficient in research, there is no full considering about the all of the factors affecting the Jintang Channel depth change, such as harbor building and some other changes near the channel; Furthermore, this paper only gives an effect of section average changes of water depth, it can't give local changes, and need to study further in the next step.

**ACKNOWLEDGEMENTS**

It would be thankful for Prof. Kong Jun and undergraduate students Mr. Sun Yunjia and Wang Jincheng's contribution to this paper. This paper is sponsored by the fund of communication from Ningbo City, Zhejiang province.

**REFERENCES**

Huang S C, Zhang S Y, Yu J. Study on the evolution of seabed of Hui Bie in Hang Zhou[J]. Journal of Sediment Research. 2005.(1):45-52.

Jiang W Z, Ma H L,Wang Z. Analysis on Flow-sediment Characteristics and Suspended Sediment Transport in Yongjiang River and the Jintang Channel.[J].Science Technology and Engineer. 2013,Vol.13(3):264-269

Jing G X. Characteristics of tidal wave and level of the Jintang Channel and the adjacent sea area[J]. Marine Science Bulletin. 1989,Vol.8(4).1-9.

Li Z H,Gao S,Shen H T. Processes of suspended sediment t transport and resuspension in Jintang Channel[J]. Journal of Sediment Research. 2006,(3):55-62.

Lu P D, Xu M. Influence of dock construction along the south shore of Jintang Channel on beach development[J]. Hydro-science and Engineering. 2002(4):24-27

Ni Y L, Li G B, Zhang M X. Analysis on scouring and silting variation in the Jintang Channel[J]. Marine Science Bulletin. 2012,Vol. 31(2):147-153.

Ren M E, Zhang R S, Cao J Y etc. Tidal inlet of China and its significance in harbor construction-----Comprehensive survey of National coastal zone and tidal flat resources. Coastal engineering Academic Conference[C]. China Ocean Press, Beijing, March,1982: 31-340.

Zhang J S, Ma L Q. Study on the stability of water intake and outlet of power plant in Beilun[R]. Nanjing Hydraulic Research Institute.2007.

Zhang J S, Kong J, Zhang W S. Calculation and analysis of the influence of coastal engineering construction of Huibie Ocean to the Yong river estuary and the Jintang Channel[R]. Nanjing Hydraulic Research Institute.2011.

Zhang J S, Chen Y P, Zhao T W. A study on current and sediment in the general layout of Yangshan Harbor[J]. Ocean Engineering. 2004 vol 22(3):67-72

Zhang J S, Liu W P. Analyses on sediment deposition along pile wharf of Waigaoqiao Port[J] Hydro-science and Engineering. March,2004.