International Conference on Estuaries and Coasts
November 9-11, 2003, Hangzhou, China

MODEL STUDY OF TIDE-DOMINATED FLAT PROFILE ON HANGZHOU BAY

Guoan ZHANG, Shenliang CHEN & Zhiying YU
State Key Lab of Estuarine and Coastal Research, East China Normal University,
Shanghai 200062, China. E-mail: gazhang@sklec.ecnu.edu.cn

Abstract: In this article, the general profile features are given by statistics method with numerous observing topography data in different years at various sections of north bank of the Hangzhou Bay. At the same time the erosion profile and deposition profile relative to coastline in this area can be distinguished with the shape of balance profile. On the basis of hydrodynamic and topography characteristics, a function relation of hydrodynamic and topography has been established in this paper. Above mentioned relation, the general equations for steady profile shape of north bank of the Hangzhou Bay, namely, equation (6) and (7), have been provided, and the model can forecast the ultimate profile shape of the local area in the course of erosion and deposition.

Key words: Hangzhou Bay, Tide-dominated, Profile shape, Profile model

1. INTRODUCTION

Profile shape of flat is a collective result of hydrodynamic effect and sediment movement. The change of flat profile shape is the form of expression of the change of coast environment. So the research for characteristics of flat profile shape will redound to analyze the change process of hydrodynamic effect and sediment movement of flat profile.

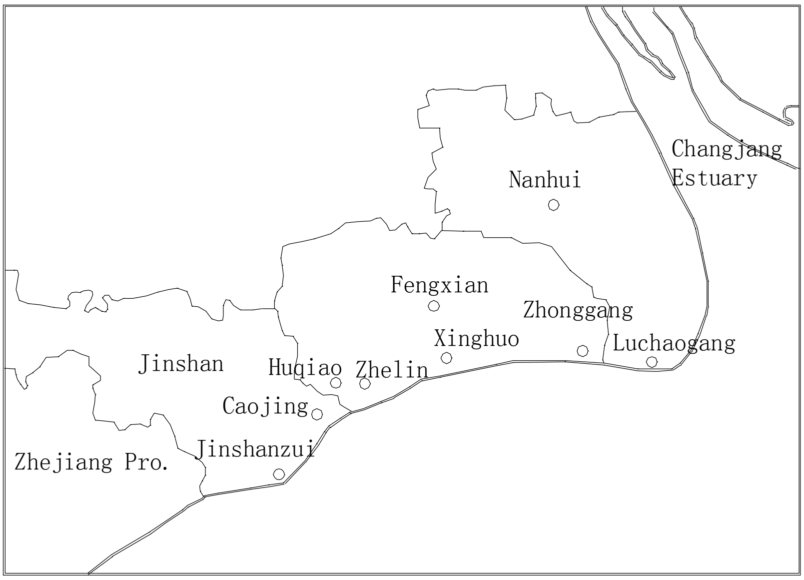


Fig. 1 Research area location

Hangzhou Bay is located at south of Changjiang delta (Fig.1), it is the famous tide-dominated silt muddy flat in China, which flat profile shape is differ from sandy flat and silt flat. In this paper, according to numerous observing topography profile data and hydrologic data of different years at Luchaogang, Zhonggang, Zhelin and Caojing sections, general characteristics of the flat profile shape and the profile development of north bank of Hangzhou Bay are analyzed.

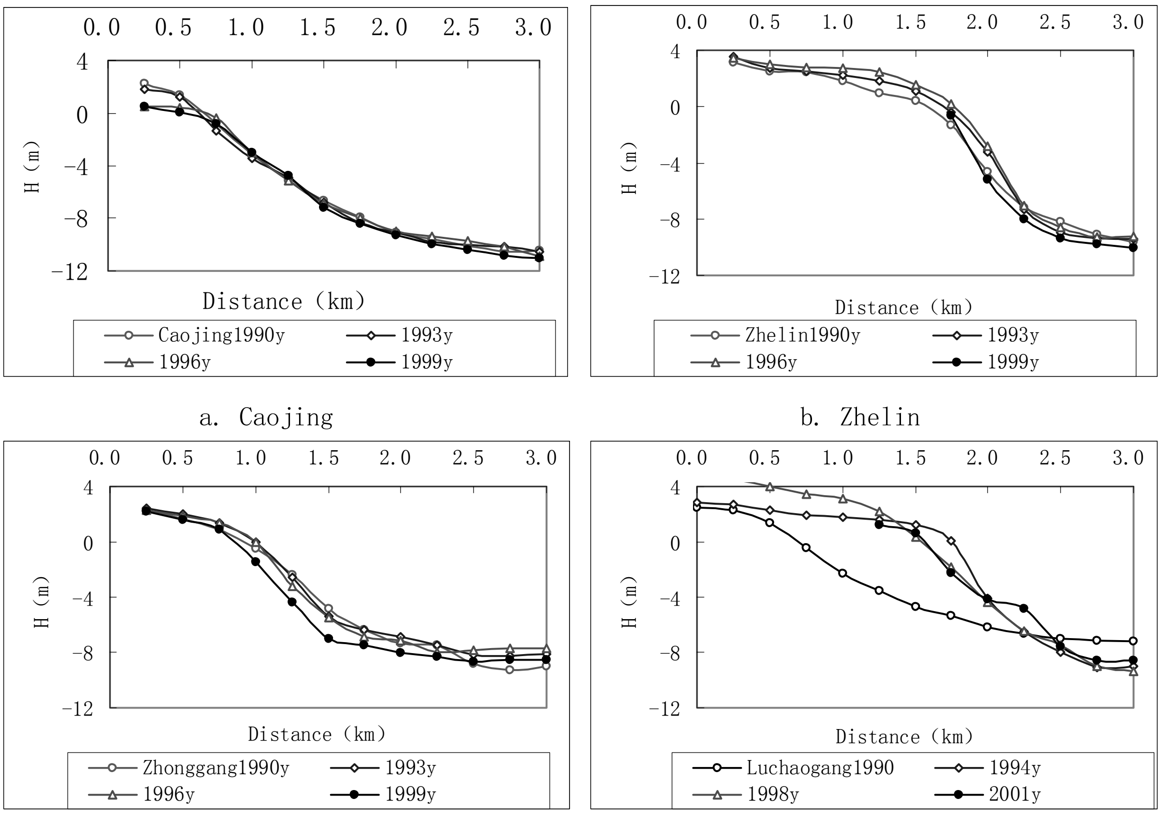
The study for flat erosion model has been developed, Long S P, and Jin Q X (1997) has discussed the erosion and deposition characteristics of flat of north bank of Hangzhou Bay by EOF method, Zhang Y and Swift D J (1998), Mehta A J (2001) Yu Z Y and Zhang G A (2002) had analyzed the flat process of erosion by dynamics method, in this paper, flat profile shape and the relation of flat profile shape & dynamics action are discussed by statistic method.

2. PROFILE SHAPE OF NORTH BANK OF HANGZHOU BAY

Referring to Fig.2, in which y is elevation, x is vertical distance to bank, profile topography distribution will be given, and profile shape will be expressed as:

$$h = f(x) \tag{1}$$

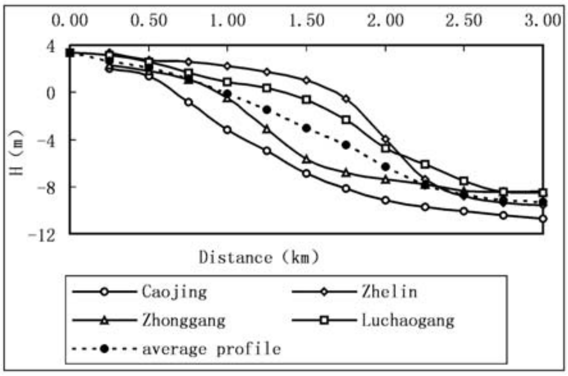
Fig.3 shows the average state of profile topography at different sections during 1990−1999 (WuSong datum plane, the same as following). To take an ulterior step to describe the profile state of erosion and deposition, the referring datum plane must be found, in this article, mathematic expected values of elevation at these four profiles above-mentioned are taken as the referring datum plane, the results are shown as Fig. 3.



a. Caojing b. Zhelin

c. Zhonggang d. Luchaogang

Fig. 2 Profile topography of Caojing, Zhelin, Zhonggang and Luchaogang



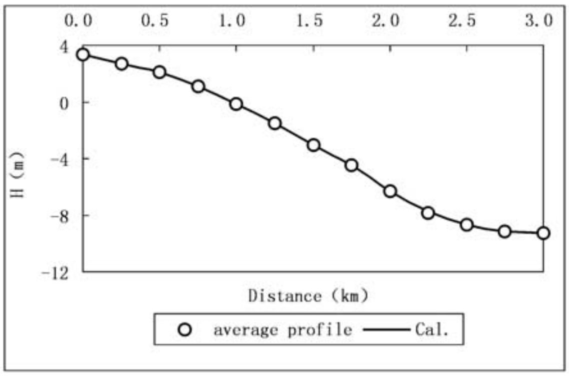


Fig. 3 State of erosion and deposition at different sections

Fig. 4 Multinomial fitting referring to datum plane

As Fig.3 shown, during 1990−1999, Luchaogang and Zhelin are in a state of general deposition. Meanwhile there are some difference between Luchaogang and Zhelin. At Luchaogang profile, flat deposits, bottom of slope and seabed is steady; and at Zhelin profile, sediment is widely deposits in flat, slope and seabed. Caojing and Zhonggang are in a state of general erosion. At Zhonggang profile, the erosion is focus on slope zone of -5.0m, and bottom of slope and seabed are in a state of slight deposition. The transition of erosion and deposition is near -9.0m. But at Caojing profile has the reverse situation of Luchaogang, flat, slope and seabed are in a state of erosion, erosion is particularly obvious in underwater slope. Furthermore, in change range of profile, erosion and deposition is mostly obvious at -5.0m, whose corresponding position is at 1.5km to bank.

Here it must be pointed that the profile state of erosion and deposition above-mentioned is the conclusion drawn from the referring datum plane. The referring datum plane represent the average profile shape in a reach of coast, which will contribute to know general state of profile on erosion and deposition. So that's more reasonable.

To take an ulterior step to analyze the profile model of erosion and deposition, according to equation (1), after multinomial fitting to referred datum plane, results are shown as follows:

$$h = 0.9642x^3 - 4.3237x^2 + 0.1157x + 3.1268 \quad (2)$$

$$R^2 = 0.9989$$

In which, x is distance to bank, whose unit is km, R is related coefficient.

3. CHARACTERISTICS OF DEPOSIT TOPOGRAPHY PROFILE

Fig.2 shows: in despite of some difference of data at various profiles, the profile of Hangzhou Bay is composed of three parts—tide flat which is generally above 0m isobath, seabed which is below -9.0m, and underwater slope which is between 0−-9.0m. There is great difference on deposition topography at different locations of profile.

Tide flat: Tide flat is generally above 0m isobath, whose chief deposit is silty mud, whose content is over 60%, whose median grain size is between 4−5Φ. In deposition topography, flat with a thin layer of yellow mud above 3.0m isobath is rather plane. In middle and low tidal flat below 3.0m, the silty bald flat is dominant. The flat is in shatter with ripple marks which being attended by lowland landforms caused by wave breaking action.

Underwater slope: between 0m and seabed, there is an obvious transition with a steep underwater slope in shape, which is the transition zone connecting flat and seabed. In this zone, alternating current is dominant, tidal current action is stronger, whose erosion action to deposit of slope is rather obvious. In components of deposit, grain size of deposit decreases gradually from upside to bottom. Taking the sample of Xinghuo reach, deposit between

0−-2.0m is coarse silt and silt, deposit between -3.0−-6.0m is silt and fine silt, and deposit below -7.0m is fine silt. The general depth of seabed is more than -9.0m, the seabed topography is smooth or with troughs, and grain size of sediment is smaller, most of them is between 0.03−0.01mm. Deposit of slope has the feature of transition. Deposit of upside slope is similar to low tidal flat, and deposit of downside slope is similar to seabed.

Seabed: Outward underwater slope, flat slope rapidly becomes plane (partly with troughs). In the Hangzhou Bay seabed, with steady source of mud and dynamical condition, distributing law of surface layer deposit of seabed is conform to that of deposit of north bank of Hangzhou Bay. In east area nearby the mouth of Hangzhou Bay, deposit is silty mud and muddy silt, whose average grain size of deposit is 7−8Φ. In middle-west area, deposit becomes coarser, and is sandy silt and silty sand, whose average grain size of deposit is 5−6Φ.

4. HYDRODYNAMICAL DISTRIBUTION AT PROFILE OF NORTH BANK OF HANGZHOU BAY

4.1 WAVE

In Hangzhou Bay, according to observing data at Tanhu station, wind wave is dominant, whose frequency is more than 80%, whose average wave height of years is 0.4m, average wave period is 2.0s; the corresponding average wave length is 6.2m.

On the basis of small amplitude wave theory, the maximal depth of wave action is about one second wave length, namely, 3.1m, whose corresponding chart elevation is about -1.0m. The index of wave breaking-H_b/d_b is about 0.3−0.4, whose corresponding location is at +0.4−+0.9m. Considering the effect of tidal change, the corresponding location is at +2.8−-1.6m. Thus it shows that the effect of wave action in this area will concentrate on flat above 0m isobath, and is slight to underwater slope at ordinarily weather condition.

4.2 Tidal current

In the area of north bank of Hangzhou Bay, the velocity distribution of tidal current is obviously in influenced by propagation direction of tidal wave from open sea and landform of coast. Owing to change of water depth and section decrease of bay, from bay mouth to interior of bay, tidal current presents features of alternating tidal current, whose velocity generally increases along the way, and whose direction parallels trend of coastwise isobath. However, in the area nearby coastline and east to Jinshanzui, due to effects of tidal wave distortion and coastwise landform, current velocity gradually decreases from Jinshanzui to Fengxian. (See Table 1)

Table 1 Statistics for coastwise measured current velocity of north bank of Hangzhou Bay (m/s)

	Flood tide		ebb tide	
	Average	Max.	Average	Max.
Zhonggang	1.65	2.77	1.29	1.76
Caojing	1.53	2.24	1.18	1.66
Jinshanzui	1.52	1.99	0.92	1.45

Horizontal distribution for coastwise current measured velocity at different depth shows obvious distribution features, namely, from sea to bank, current velocity gradually decreases with decrease of water depth (See Table 2).

Since astronomical conditions have variances at different time of observing tidal current, it will be impossible to compare tidal current at profiles in the area. Therefore, harmonic analysis for the observing tidal current data of 25 correlative survey stations at different time and location has been carried out, and the maximum possible velocity affected by astronomical tide also has been calculated, then the observing data can be compared(Fig.5).

Table 2 Horizontal distribution for maximum measured current velocity of north bank of Hangzhou Bay (m/s)

	Luchaogang	Zhonggang	Xinghuo	Jinhui	Huqiao	Caojing	NanShe
+2.5−+2.0m		0.31		0.47		0.38	
+1.0−+0m		0.43	0.63	0.92	0.65	0.55	1.06
-2.0m						1.01	
-5.0m	1.96	2.77	1.92	1.42	1.81	1.28	1.36
-8.0−-9.0m	2.22	2.76			1.73	2.16	1.39

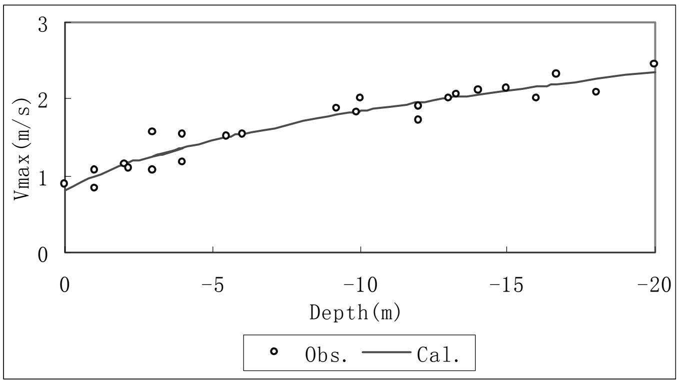


Fig. 5 Distribution for maximal possible current velocity

After fitting the maximum possible velocity of different stations above-mentioned, it will be drawn that

$$V_{\max}(x) = h(x)^{1/3} - b$$

$$R^2 = 0.92 \qquad (3)$$

Where b is coefficient, which will be slight different with different area, in this paper *b*=0.45; *R* is correlative coefficient.

4.3 SEDIMENT CONCENTRATION

Sediment concentration is the other important factor to affect landform evolvement of profile. But the affection is macrographic. It need further study to analyze the concrete evolvement for flat profile. Lack of data at different survey stations during enough long time and multitudinous affection factors are the difficulty to affect study.

Hangzhou Bay is famous with its high sediment concentration, whose average is about 1.5−2.0kg/m^3. The vicinity of Nanhuizui is the area of high sediment concentration whose average reaches 3.0 kg/m^3, meanwhile the vicinity of Jinshanzui is the area of low sediment concentration whose average is only 0.5−1.0 kg/m^3. The seasonal difference for sediment concentration within a year is obvious, and sediment concentration on flat also changes obviously with wind wave variation. That leads to the indeterminacy to describe the distribution principle for profile sediment concentration. Furthermore, variation of sediment concentration and current variation aren't synchronous, and variation of sediment concentration always delayed current variation. That farther increases the difficulty to solve this problem with dynamics method.

5. THE MODEL STUDY OF TIDE-DOMINATED FLAT ON HANGZHOU BAY

5.1 THE MODEL STUDY OF TIDE-DOMINATED FLAT ON HANGZHOU BAY

Profile mode of tide-dominated silt muddy flat has several models, which are all considered from the view of dynamics, and have greatly contributed to the study for mechanism of flat evolvement. However, there is much difficulty in practice. With natural condition, landform evolvement is a long periodical process (e.g. unit in year). With great variation of velocity and sediment concentration within a year, how to make observing data have representation is the precondition of successful model. Furthermore, it's very difficult to gain lots of synchronous dynamic and sediment data at different locations.

So it is significance to research profile evolvement with statistic method. Hangzhou Bay is famous with strong tide and high sediment concentration to which landform variation is well related. In the above discussion, we have drawn the correlative relation of water depth and the maximum possible velocity affected by astronomical tide. The relation can be regarded as the relation under the state of steady profile since that is on the basis of numerous observing data. Therefore, the model for concrete profile evolvement can be shown as:

$$h(x) = (V_{max}(x) + b)^3 \qquad (4)$$

$$\Delta h(x) = (V_{max}(x) + b)^3 - h_0(x) \qquad (5)$$

The maximum possible velocity also is a variable of time, and changes with outer current conditions and landform, thus profile landform will present the process transit of erosion and deposition. Then, that equation (3) and (4) change with time can be shown as:

$$h(x,t) = (V_{max}(x,t) + b)^3 \qquad (6)$$

$$\Delta h(x,t) = (V_{max}(x,t) + b)^3 - h_0(x,t) \qquad (7)$$

Equation (5) represents theoretic balance profile; equation (6) shows height for erosion or deposition of theoretic value and practical value. The height isn't related to the process which has happened. On the contrary, equation (2) represents the process which has happened.

5.2 APPLICATION OF THE MODEL STUDY OF TIDE-DOMINATED FLAT ON HANGZHOU BAY

Taking an example of western Caojing profile, according to the tidal current data in Nov., 1996, the most possible velocity and the corresponding theoretic depth are calculated. The results show as Fig.6 and are same as the trend of observing landform of 2001. The calculation shows that with condition which current velocity didn't change, seabed has approached the state of steady profile, and slope will be eroded 1-2m. November.

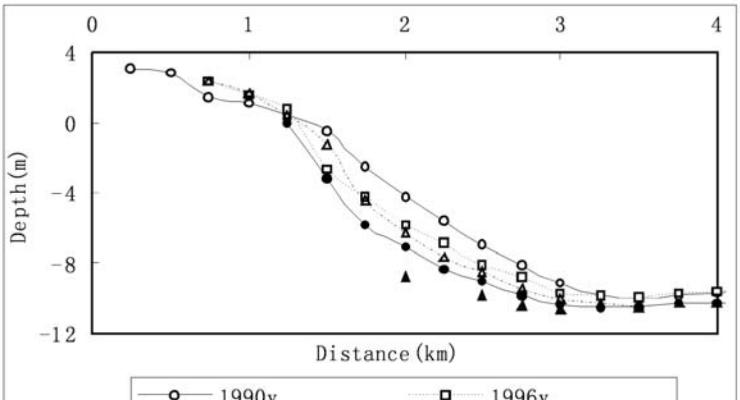


Fig. 6 Profile Development of Caojing

6. CONCLUSION

Hangzhou Bay is the famous tide-dominated silt muddy flat in China, whose flat profile, which shows reversed S-shaped, is composed of three parts—tide flat, underwater slope and seabed. Tide flat is generally above 0m isobath, seabed which is below -9.0m, and underwater slope which is between 0~-9.0m. There is great difference on deposition topography at different locations of profile.

According to numerous observing topography data of different years at various sections of north bank of Hangzhou Bay, by statistics method, equation (2) gives general profile features, at the same time it can distinguish erosion profile and deposition profile relative to coastline in this area.

In this paper, on the basis of hydrodynamic and topography characteristics, the function relation of hydrodynamic and topography has been established, the general model for steady profile shape of north bank of Hangzhou Bay, namely, equation (6) and (7), have been provided, and the model can forecast the ultimate profile shape of the local area in the course of erosion and deposition.

ACKNOWLEDGMENTS

This study was supported by National Natural Science Foundation of China, No. 40276027 and 40071014.

REFERENCES

Long S P, Jin Q X, 1997, A Study on Nearshore Profiles From Nanhui to Fengxian Along the North Bank of Hangzhou Bay with 3D-EOF. Journal of ECNU (Natural Sciences), 1:69-76.

Zhang Y, Swift D J P, Yu Z Y, Jin Liu, 1998, Modeling of Coastal Profile Evolution on the Abandoned Delta of the Huanghe River. Marine Geology, 145:133-148.

Mehta A J, 2001, Modeling Muddy Coast Response to Waves, J. of Coastal Res. SI. No.27. P.137-148.

Yu Z Y, Zhang G A & Jin L, 2001, Evolution Prediction of the Abandoned Yellow River Submerged Delta under Wave and Current. Oceanologia ET Limnologia Sinica, Vol.33, 6:583-590.