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INFLUENCE OF HANGZHOU BAY MAJOR BRIDGE ON WATER ENVIRONMENT

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Abstract: The Hangzhou Bay Major Bridge from Zhengjiadai to Shuiluwan is 36 km in length and it is the longest bridge across a sea in the world. A physical model is used for investigating the influence of the Hangzhou Bay Major Bridge on the water environment such as the tidal level, velocity, tidal volume, flood and Qiantang Bore. The model obeys similarity criteria for gravity, resistance and flow continuity. It is molded according to the chart in September 2000 and verified well with hydrometric data at the same time. The research indicates that the influence of the Hangzhou Bay Major Bridge on the flow of the Qiantang Estuary is mostly limited nearby the bridge, and on the Qiantang Bore and flood is little in essence.

Key words: Physical model, Similarity criteria

1. INTRODUCTION

The Hangzhou Bay Major Bridge from Zhengjiadai to Shuiluwan is 36 km in length (see Fig.1) and it is the longest bridge across a sea in the world. There are more than 600 spans for the bridge and most of bridge span is 50m to 70m except northern and southern navigable openings. A physical model is used for investigating the influence of the Hangzhou Bay Major Bridge on the water environment such as the tidal level, the velocity, the tidal volume, the flood and the Qiantang Bore.

2. GENERAL FLUVIAL CHARACTERISTICS IN QIANTANG ESTUARY

The Qiantang River empties into the East China Sea through the funnel-shaped Hangzhou Bay. Because the quantity ratio of the river runoff and tidal flow is rather small, a large amount of sediment originating from the Changjiang Estuary has been carried in by flood tidal current and deposited to form a large longitudinal sand bar 130 km in length from Zhapu to Wenyan. As the tidal wave propagates into the funnel-shaped Hangzhou Bay, the tidal range increases. When it climbs in the shallow slope upstream of Ganpu, the wave deforms violently and the wave front becomes steep, then breaks to form a tidal bore near Jianshan. In the stretch between Babao to Ganpu- the Jianshan Bend, being very wide and shallow, undergoes frequently erosion and siltation, and its channel wanders north and south in a width of more than 10 km. Along the northern coast of the Hangzhou Bay from Ganpu to Jinshan, there is a stable deep channel- the Northern Channel- suitable for harbor construction and navigation. The flood/ebb velocity during spring tide in the Hangzhou Bay is about 2.0/1.5

m/s near the mouth, increasing toward the apex of the Bay (Ganpu) to 3.0/2.5 m/s. Near the mouth of the bay and along the northern channel, the sediment concentration averages 0.7−1.0 kg/m^3, while in the Jianshan Bend and along the south coast of the bay near Andong, the concentration becomes quite large, about 2.5−5.0 kg/m^3. Both the suspended load and bed material are principally composed of fine silt with clay content less than 10% and that is easily scoured.

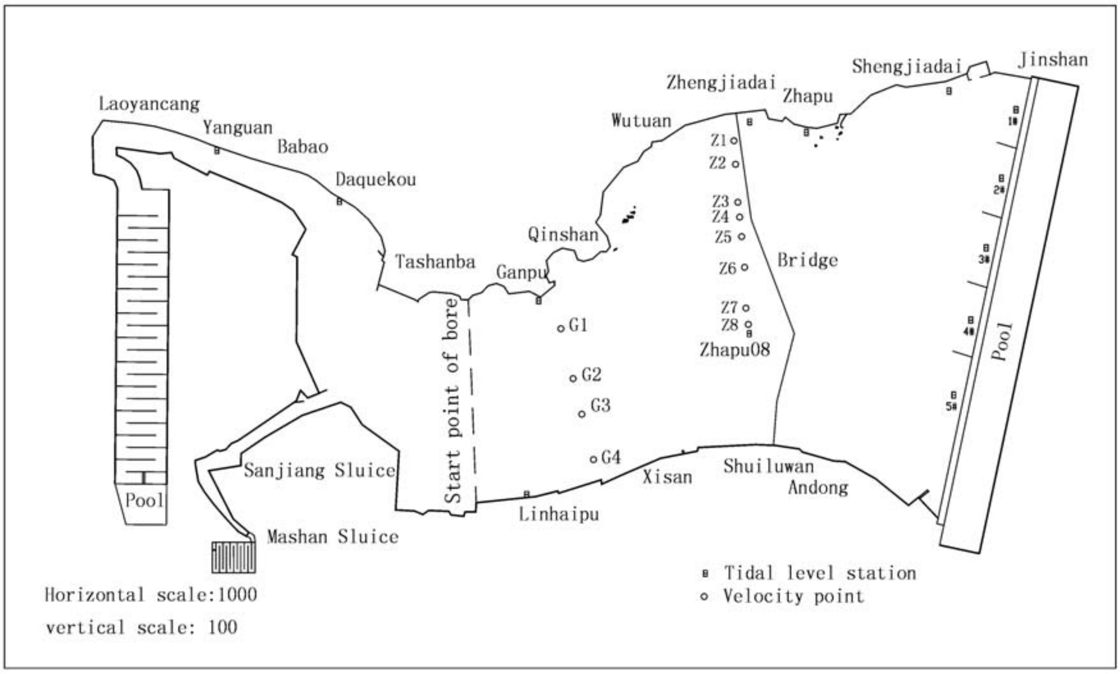

Fig. 1 Layout of model for Hangzhou Bay Major Bridge

3. DESIGN AND VERIFICATION OF PHYSICAL MODEL

3.1 MAJOR SIMILARITY CRITERIA

In general, the prototype-to-model ratio of a physical parameter x is called the scale of the parameter x, that is

$$\lambda_x = \frac{x_p}{x_m} \tag{1}$$

Where, x_p is the value of parameter x in the prototype and x_m in the model.

The following plane two-dimensional unsteady flow equations of momentum and continuity are used in deducing flow similarity criteria:

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + g\frac{\partial z}{\partial x} = -g\frac{u\sqrt{u^2+v^2}}{C^2 R} + 2\omega_e v \sin\varphi \tag{2}$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + g\frac{\partial z}{\partial y} = -g\frac{v\sqrt{u^2+v^2}}{C^2 R} - 2\omega_e u \sin\varphi \tag{3}$$

$$\frac{\partial h}{\partial t} + \frac{\partial}{\partial x}(uh) + \frac{\partial}{\partial y}(vh) = 0 \tag{4}$$

Where u and v are vertical averaged velocities in the direction of x, y; and h, z, R, C, g, ω_e and φ are water depth, tidal level, hydraulic radius, Chezy coefficient, acceleration of gravity, angular velocity of earth rotation, and local latitude, respectively.

The gravity and flow continuity similarity scales can be deduced by using similarity transformation from (2)−(4) as shown in Table 1.

Resistance similarity can be deduced from (3) as

$$\lambda_c^2 = \frac{\lambda_l}{\lambda_R} \tag{5}$$

For the wide and shallow Qiantang Estuary, the bank resistance can be neglected and

$$\lambda_R \approx \lambda_h, C = \frac{1}{n} R^{1/6} \tag{6}$$

Replacing the scaling form of (6) into (5), one gets roughness coefficient scale as shown in Table 1 too.

Table 1 Similarity scales

Scale	Equation	Adopted
Horizontal	λ_l	1000
Vertical	λ_h	100
Velocity	$\lambda_u = \lambda_v = \lambda_h^{1/2}$	10
Current time	$\lambda_t = \lambda_l / \lambda_u$	100
Roughness coefficient	$\lambda_{n_b} = \lambda_h^{2/3} / \lambda_l^{1/2}$	0.68

3.2 MODLING AND VERIFICATION OF THE MODEL

Laoyancang and Jinshan are selected as upstream and downstream boundaries of the model respectively. Horizontal scale $\lambda_x = \lambda_y = \lambda_l = 1000$ and vertical scale $\lambda_z = \lambda_h = 100$ are chosen. The model was molded according to the chart of September 2000 and verified well with hydrometric data (10 tidal level stations and 12 velocity points) at the same time. The verified results of 6 tidal level stations and 8 velocity points at Zhapu river section during spring tide are shown in Fig.2 and Fig.3.

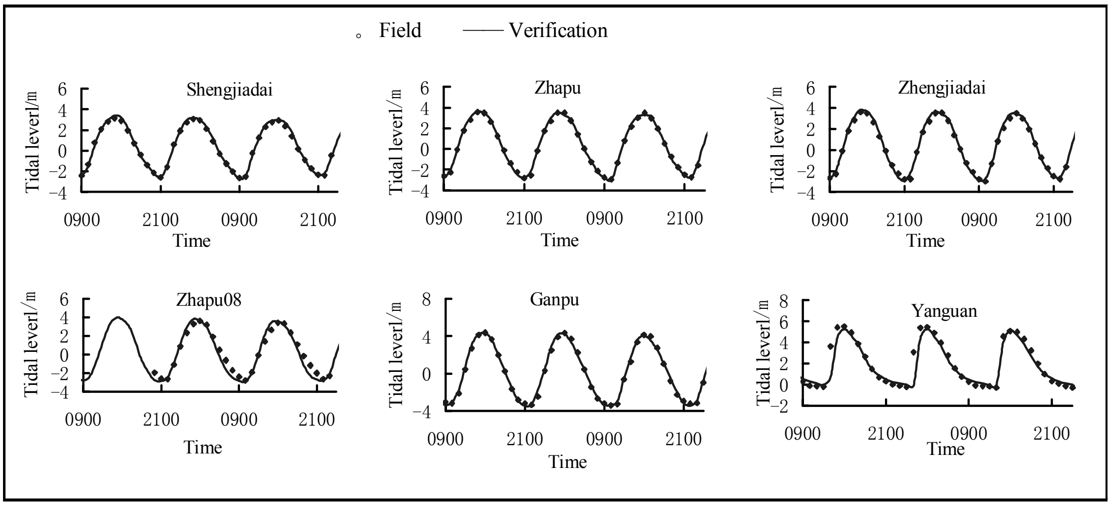

Fig. 2 Comparison of tidal curves during spring tide

4. ANALYSIS OF INFLUENCE OF HANGZHOU BAY MAJOR BRIDGE TO WATER ENVIRONMENT

The flow at Hangzhou Bay is controlled by tide. In order to research on influence of Hangzhou Bay Major Bridge to flow and the Qiantang Bore, the spring tide for the frequency of tidal range p=0.33%, 1% and the annual averaged runoff are used for boundary conditions at downstream and upstream respectively according to the concerned norms made by Ministry of communication and Ministry of water conservancy.

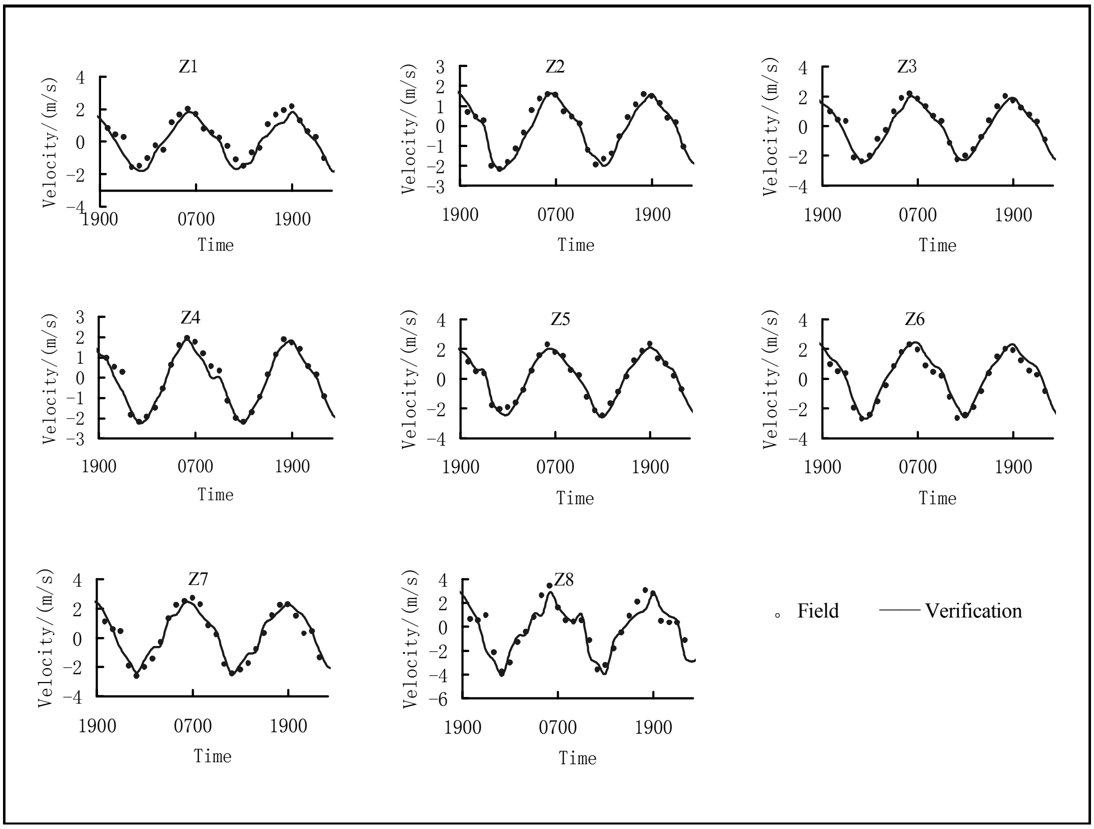

Fig. 3 Comparison of velocity graphs during spring tide

The test indicates that the high lever downstream and upstream of the bridge will increase and decrease respectively during flood tide and the lower lever upstream and downstream of the bridge will increase and decrease respectively during ebb tide (see the Fig.4). The influence of the bridge on velocity occurs near the bridge (see the Fig.5). The velocity will decrease less than 6 % except in the middle part of the bridge span and near the head of the bridge pier. After constructing bridge, the tidal value will decrease less than 5% near the bridge (see the Table 2).

The Hangzhou Bay Major Bridge is located 32 km downstream of starting point of Qiantang Bore. The height of tidal head at Yanguan is 2−2.5m during spring tide on autumn. The model test indicates that after construction, the height of the tidal head at Yanguan will only lower 0−0.02 m (average value for many tests) during the spring tide for the frequency of tidal range p=1%, less than its 1%. Therefore, the influence of the Hangzhou Bay Major Bridge to the Qiantang Bore is little in essence.

The river reach upstream of Babao is mainly controlled by runoff. The Hangzhou Bay Major Bridge is located 60 km downstream of Babao. The current process of cross section at Daquekou (not so far downstream of Babao) is not changed essentially (to the flood for the frequency of p=1%) after constructing bridge. So, there is not influence of bridge construction on the flood.

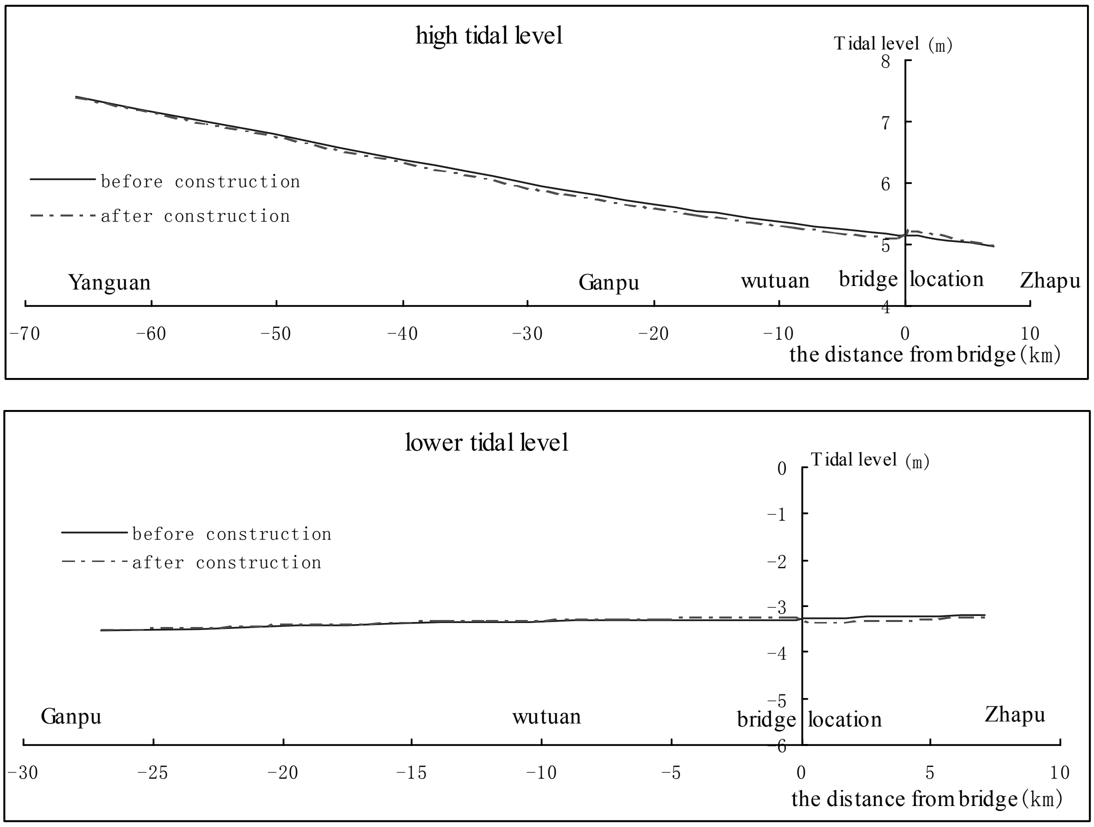

Fig. 4 Changes of high and lower level before and after constructing bridge (the spring tidal for frequency of tidal range P=0.33%)

Table 2 Change of tidal volume after bridge construction (%)

Tide type	Type of tidal volume	1.3 km upstream of bridge	Ganpu section
General spring tide	Flood tide	-3.57	-1.03
	Ebb tide	-3.44	-0.73
Spring tide for frequency of p=1%	Flood tide	-4.31	-1.36
	Ebb tide	-4.12	-0.98
Spring tide for frequency of p=0.33%	Flood tide	-4.82	-1.49
	Ebb tide	-4.57	-1.38

5. CONCLUSION

There is a small influence of Hangzhou Bay Major Bridge to the tidal level, the velocity and the tidal volume and it occurs near the bridge. There is not influence of bridge construction on the flood. The influence of the bridge to the Qiantang Bore is little in essence.

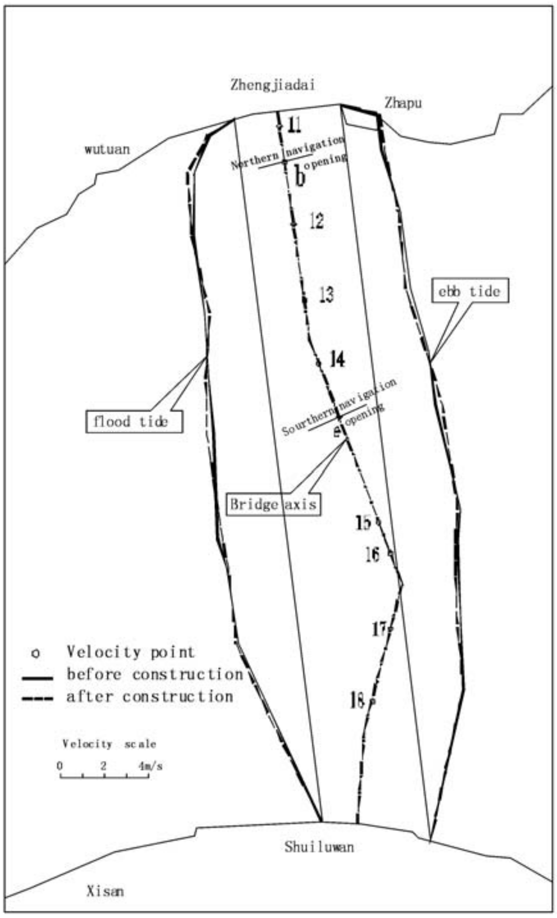

Fig. 5 Changes of the rapid velocity in flood and ebb tide before and after constructing bridge (the spring tidal for frequency of tidal range P=0.33%)

REFERENCES

Shaolong Xiong etc, 2001, Feasible Research of Hangzhou Bay Access Project, Experimental Report for Physical Model , Technique Report, Zhejiang Institute of Hydraulics and Estuary, Hangzhou, China (in Chinese).

Shaolong Xiong etc, 2002, Physical Model for Hangzhou Bay Major Bridge and Research on Local Scour of Bridge Span, Technique Report, Zhejiang Institute of Hydraulics and Estuary, Hangzhou, China (in Chinese).

Shaolong Xiong etc, 2002, Design and Verification of Physical Model for Hangzhou Bay Major Bridge, Donghai Marine Science, 2002 No.4 (in Chinese).