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A SUPER-LARGE TIDAL PHYSICAL MODEL FOR THE PEARL RIVER ESTUARY

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Abstract: The Pearl River Estuary is one of the most complex estuaries in the world. It consists of more than 200 waterways forming a river-network at the Pearl River Delta. It receives the water coming from the West River, the North River and the East River and discharges the water into the Southern China Sea through eight outlets. The estuary area is the place where both the fresh water from upstream and the tide flow from the sea coexist with each other. This paper briefly introduces the existing problems in the estuary area, the feasibility of the large-scale model study, the techniques related to the model design and tide reproduction and the control of the super-large tidal scale model, as well as some experiments currently carried out on the model.

Key words: Scale model, Pearl River Estuary, Tidal flow, River-network

1. INTRODUCTION

The Pearl River estuary is a typical delta estuary located at the south part of Guangdong province. It receives water coming from the West River, the North River and the East River. There are more than 200 waterways in the delta area and the water in these waterways flows in different directions, forming a very complex river-network. The average waterway density reaches 0.81 km waterway length per square kilometers. The total area of the estuary is about 26820 km^2.

The upstream runoff flows through the waterways in the delta area and then discharges into the South China Sea through 8 outlets, named (from east to west): Humen, Jiaomen, Hongqili, Hengmen, Modaomen, Jitimen, Hutiaomen and Yamen. There are two bays in the estuary, i.e., the Lingdingyang Bay and the Huangmaohai Bay, which link outlets of rivers to the sea. The freshwater from Humen, Jiaomen, Hongqili and Hengmen discharges into Lingdingyang Bay and the water from Hutiaomen and Yamen discharges into Huangmaohai Bay, but the water from Modaomen and Jitimen discharges into the sea directly. Due to "three rivers' freshwater entering into it and discharging from it into the sea through 8 outlets", the estuary is one of the most complicated estuary in the world.

2. CURRENT PROBLEMS IN THE ESTUARY

In recent two decades, with the rapid economic development in the Pearl River Delta, hundreds of bridges have been built cross rivers; large scale reclamation has been carried out on beaches or shallow water area along the coast; a huge amount of sands has been excavated from rivers as construction material, and etc. These human activities, most of which are disordered, have obviously influence on the natural evolution of the estuary and result in the change of the upstream net-rivers discharge distribution in the Pearl River Delta.

Presently, water induced problems in the Pearl River estuary include:

- In some waterways, water levels are increasing during flood period, which causes many difficulties for the flood prevention in these areas.

- The capacity of draining the water-logging in lower lands is too low and the water-logging disaster is getting serious.
- The navigation channels in the estuary area are depositing by the sediment transported from the upstream.
- The variations in water quantity and water quality are bringing an unfavorable influence on the water ecosystem.
- The disordered reclamation of beaches, shallow water areas and riverbanks are causing flood problems and regional conflicts.

These problems are expected to be timely solved in order to ensure the sustainable development of the Pearl River estuary area.

3. FEASIBILITY OF SCALE MODEL EXPERIMENTAL STUDY

Preventing flood disaster in Pearl River Delta area is one of the most important tasks for water resources departments. For this purpose, some engineering programs are proposed recently including: comprehensive development of the Pearl River estuary, improving capacities of some outlets for flood and sediment discharge.

In past years, many studies, including experiments on scale models, were carried out for hydraulic engineering projects in the Pearl River estuary area. However, due to the limitation of basic conditions and the technique it was difficult to construct an integral model for the whole Pearl River estuary. Only partial models of the Pearl River estuary have been carried out for the Lingdingyang Bay, Modaomen, Jitimen and Huangmaohai, respectively.

Since rivers in the Pearl River estuary are connected each other and form an integral river-network system, those partial models can not be used to study problems with multiple-purpose regulation for the integral water system. One example is "Study on suitable distribution of the water and sediment transport among network-rivers in the Pearl River estuary", which is supported by the Ministry of Water Resources. Since the distribution of water and sediment transport among waterways is highly related each other, it is essential to take the Pearl River Estuary as an integer to study the water and sediment transport. The experimental results will supply scientific data to guide the comprehensive development of Pearl River estuary. To carry out such an important experiment, a super-large tidal scale model for the whole Pearl River estuary area is needed.

As the flood control becomes more important issue, the government and the public are increasing the investment for water conservancy. With the financial support from government and public, some fundamental works for the regulation of the Pearl River estuary have been carried out. A comprehensive topography measurement for the main rivers of the Pearl River including outlets has been carried out in 1999. The water flow and sediment transport measurements in the dry season and in the flood season have been carried out in February 2001 and July 1999, respectively. A 100,000m^2 experimental hall and site were constructed in 1998. All these fundamental works are the necessary conditions for the construction of the integral model for the Pearl River estuary.

4. DESIGN OF MODEL

4.1 GENERAL REQUIREMENTS FOR BUILDING THE MODEL

For studying different subjects, the model should be designed according to the general requirement of multi-purpose studies. The model design should not only take the present practical investigation issues into account but also for the future researches.

For simplifying the model boundary controlling, the model should enclose an integral water system with a simple boundary. The up boundaries of the model include: the Sixianjiao which is the first link between the West River and North River; the Shilong of the East River, the Laoyagang of the Liuxihe River; the Shizui of the Tang River. The down boundary is chosen in the Southern China Sea with the –25m elevation contour line. The Hong Kong and Macao water areas are enclosed in the model as well (see Fig.1).

The model is designed for multi-purpose studies for different engineering projects in different water areas as mentioned below.

In the shallow sea region:

The investigation issues mainly include the improving plan of the estuary including eight outlets; plans of large ports or piers building along the coastal; large navigational channel dredging plans; plans of huge bridges cross rivers or the sea; and the water pollution in this region; and etc.

In the river-network region:

Research issues mainly include the investigation of the flood control plans, study of the reasonable distribution of the water and sediment among rivers, as well as study of the distribution of water resources in this region and etc.

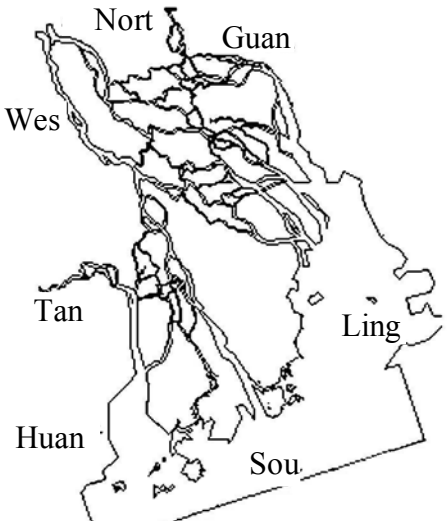

Fig. 1 Sketch of the model

In the river-network and outlet regions:

Issues to be investigated mainly include the influences of various engineering projects on the flood prevention and the distribution of the water and sediment among rivers, as well as the influences of various regulation projects within the river-network region on the water flow and sediment transport, the sedimentation at the outlets, and etc.

4.2 SCALE RATIOES BETWEEN MODEL AND PROTOTYPE

The determination of physical quantities scale ratio between the model and the prototype relates to many factors. Considering the available field size, the horizontal scale ratio of the prototype to the model is determined as 700. According to similarity laws and necessary conditions, other scale ratios of physical quantities between the model and the prototype are determined as Table 1.

Table 1 The scale ratios of the model

Scale ratio	Horizon. length	Vertical length	distort	velocity	roughness	time	discharge
symbol	λ_L	λ_H	η	λ_V	λ_n	λ_T	λ_Q
value	700	70	10	8.37	0.64	83.67	409963

The construction of the super-large tidal scale model for the Pearl River Estuary was finished in 2000; Now, some experiments are carrying out on the model. The model is characterized by

- Advanced tide control technique — an automatic tide control system is applied to the model to control the tide generation of multi-boundaries.
- Large scope — the model covers land 25,000m^2, in which water area is about 15,000m^2,

including 66 rivers or waterways. The tide-generating boundary width of the model at downstream reaches 170m.

- Long-term utilization — the model will serve for studying water-related problems in the Pearl River estuary for a relatively long time.
- Good environment — the environment around the model is quiet and suitable for scientific research experiments.

4.3 FEATURES OF THE MODEL AND EXPERIMENTS

The model and experiments have following features:

- The integral model can be separated as three parts, i.e., the Lingdingyang part, the Modaomen part and the Huangmaohai part, so that the cost of experiments can be reduced when local engineering projects are studied. Correspondingly, the model boundaries are designed to be changeable.
- More than 70 underwater pumps are installed along the down boundary pool of the model to reproduce the tidal current and controlled by computers (see Fig.2). With these equipments the tidal current can be reproduced more smoothly and the environment of experiments becomes quieter than before.
- The data measurement on the model, such as the water level and flow velocity, can be automatically transported to the computer center. The tide reproducing system and the data measuring system are combined together, forming an integral tidal model control system. This system is advanced.
- Two different ways measure the flow velocity on the model: The key point velocities are measured by normal spin wheel apparatus; the surface velocities in concerned areas are measured by PIV/PTV, a advanced surface flow image analyzing system.

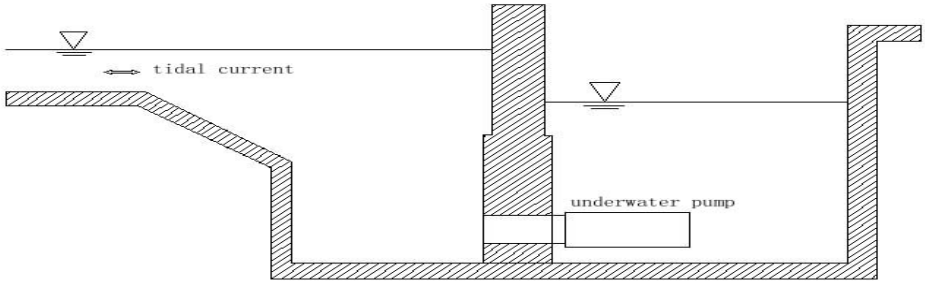

Fig. 2 Reproducing the tidal current with underwater pumps

4.4 THE TIDE REPRODUCTION TECHNIQUE ON THE MODEL

At present, reproducing the tidal flow field on the model is one of the most complex techniques. According to field data analysis, there is a transverse ocean current along the down boundary of the model. It is very important to reproduce this kind of flow phenomenon correctly. However, it is difficult to achieve this.

Based on analyzing the tidal characteristics along the coastal area, the down tidal boundary of the model is separated into six parts (see Fig.3). The tidal level process in each part is preliminary given according to its prototype. By carefully modifying the tidal level process in each part the transverse flow on the model can be reproduced similar to the prototype. Due to the interference of water levels between parts, it is difficult to control the tidal process for all six parts. With great efforts of the researchers, the technique of model's tidal controlling

technique has gotten significant progress. Based on the advanced tidal controlling technique, the large tidal model can be functioned properly.

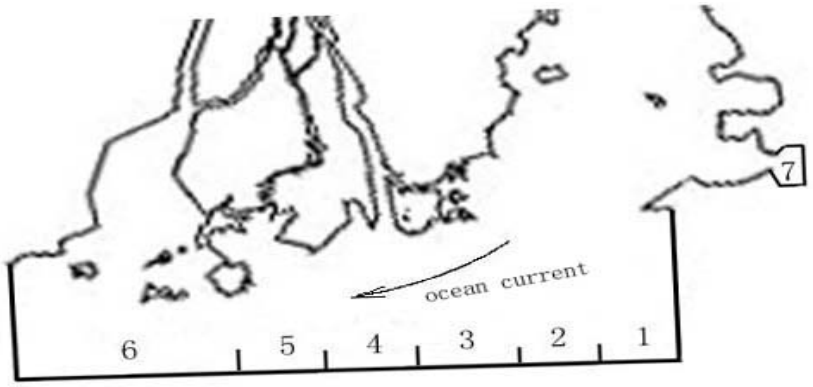

Fig. 3 The ocean current along the down boundary

5. EXPERIMENTS ON THE MODEL

A series of important experiments related to the integral situation of Pearl River estuary are now under consideration by the Pearl River water Resources Commission and will be carried out on the model. The large scale model, as one of the most important research techniques, will play an important role in planning and designing of large engineering projects in the Pearl River estuary.

After carefully validation, the model is now used for different kinds of experiments which include:

- Experiments for the comprehensive development of the Pearl River estuary.
- Experiments of the discharge distribution of the West River and the North River in the flood season.
- Experiments of the suitable distribution of water discharge and sediment transport between waterways in the river-network.
- Experiments of the water resource distribution in the Pearl River delta area in the dry season.
- Experiments for verifying the bank guide-line in the Pearl River estuary.

In addition, some hydraulic engineering projects, such as harbors, bridges, reclamations, navigational channels and etc. have been or plan to be constructed in the estuary area. The corresponding experiments should be carried out on the tidal model.

6. CONCLUDING REMARKS

The Pearl River Estuary is a typical Delta estuary. The waterways in the estuary form a network and complex system. With rapid economic development in the delta, it is urgent to investigate issues related with the flood control, influence of various projects, as well as water resources in the estuary. To achieve this, a supper-large tidal scale model for the estuary has been successfully established based on some fundamental work. The model is equipped with advanced tide reproducing and new measuring instruments. Currently, some experimental studies are carrying out on this model. There will be lot of technical problems in future experiments on the super-large tidal scale model. This paper gives out some issues considered during the model building period and the authors of this paper would like to consult to the experts in this field for new technical problems occurring in future modeling experiments and share experience with them.