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Hydrolink

THE CHANGJIANG RIVER FLOOD PROTECTION PHYSICAL MODEL

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The Changjiang River (formerly named the Yangtze River), is the largest river in China. The drainage basin of the river is a key area in China in terms of politics, economy, and culture with an abundance of water and mineral resources.

Despite this, frequent and severe floods from the Changjiang River are significant threats to the nation. For example, in the 20th century alone, four extreme floods occurred in the drainage basin of the Changjiang River; namely the 1931, 1935, 1954 and the 1998 big floods, which had devastating effects that significantly impacted socioeconomic development. The Three Gorges Project (TGP), one of the largest hydropower complex projects in the world, plays a key role for the improvement and development of the Yangtze River. The TGP started operating in June 2003, and improved considerably flood protection conditions in the downstream reaches of the river. However, the operation of the TGP also changed the hydrological regime of the downstream river and led to new conditions as outlined below:

(1) The decreasing sediment concentration in the river downstream of the TGP will induce scouring and silting over significant periods of time in the channel. Consequently, this will cause changes in the river flow regime and affect the security of dikes, slope protection works and river regulation works, etc.

(2) The scouring and downcutting of the channel downstream of the TGP and the corresponding decline of the water stage in the river will most likely change the flow and sediment diversion from the Changjiang River to the Dongting Lake via the "three outlets"; namely the Songzikou, Taipingkou and the Ouchikou (see Figure 1). The balance of the river-lake (i.e. Changjiang River-Dongting Lake) system will then be disturbed resulting in changes to fluvial processes and flood protection accordingly. Therefore, it was decided there was a need to build physical models for key flood protection sections of several river reaches in order to study the above mentioned issues in combination with numerical model simulations and prototype data analysis.

In 2003, the decision was made to build the Changjiang River Flood Protection Model (CRFPM) in Wuhan. The CRFPM, primarily consisted of large range physical model tests

Figure 1. Modeling area of the CRFPPM

Similarities	Scales	Value of scale
Geometrical similarity	horizontal scale (α_L)	400
	vertical scale (α_H)	100
Flow dynamic similarity	velocity scale (α_v)	10
	roughness scale (α_n)	1.08
	discharge scale (α_Q)	400000
	time scale (α_{t1})	40
Sediment dynamic similarity	incipient velocity scale (α_{V0})	10
	particle size scale (α_d)	0.9
	fall velocity scale (α_w)	2.5
	sediment concentration scale (α_s)	0.75
	time scale (α_{t2})	135

Table 1. Summary of the model scales

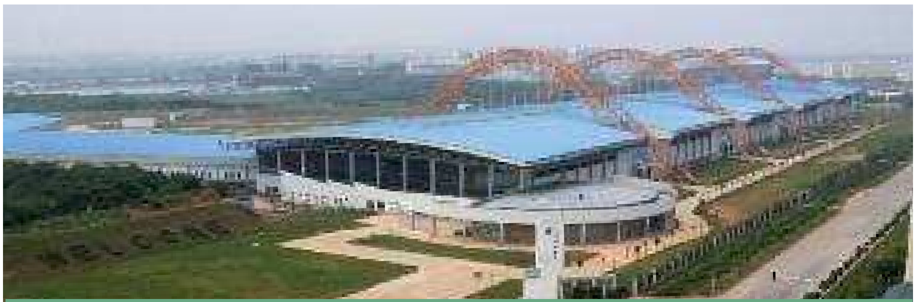
Figure 2. Experimental hall of the CRFPPM


Figure 3. Control center of the CRFPPM

combined with numerical and prototype data analysis, in order to investigate the river-lake system evolution, the flood protection situation and the countermeasures for the middle and lower reaches of the Changjiang River after the TGP operation. The CRFPM aims at providing a scientific basis for flood protection planning, engineering construction and flood protection decisions. .

The Changjiang River Flood Protection Physical Model (CRFPPM) includes

- the Changjiang River from Zhicheng to Luoshan (about 400 km long), wherein the reach from Zhicheng to Lianhuatang (347.2 km long) is called the Jingjiang Reach,
- the Dongting Lake,
- the downstream end reach of the four main tributaries of the lake, i.e. rivers Xiang, Zi, Yuan and Li (see Figure 1),
- the three outlets and
- the many small channels connecting the Changjiang River and the Dongting Lake.

The horizontal and vertical scale of the CRFPPM is 1:400 and 1:100 respectively (see Table 1 for a summary of the model scales). Construction for the CRFPPM started in March 2004, and was basically completed in December 2005.

Facilities and equipment of the CRFPPM

The CRFPPM includes a 60,000 m2 experimental hall (Figure 2), the physical model, water and sediment supply system, control and measuring system and other relevant facilities such as the control center (Figure 3).

The choice of scaled sands used in the physical model tests is key to garnering successful experiment datasets. After more than two years of continuous testing and verification, special compound plastic model sands with various fine characteristics have been developed and produced.

The CRFPPM is equipped with advanced experimental measuring and control systems. The experimental automatic measuring and control systems consist of an observation and control network, measuring subsystems of flow rate, water stage, flow velocity, tailwater level, sediment supply, river channel topography, image monitoring and sediment analysis, etc. The systems are capable of real-time data acquisition and control and processing of various parameters during experiments.

Brief overview of research activities and achievements

After construction, verification of the CRFPPM was undertaken in 2006 to 2007. In 2008 the CRFPPM began to take on research projects. So far, more than 40 state, provincial or ministerial level scientific research projects have been conducted by the CRFPPM. Sources of funding for these projects are the National Key Research and Development Program of China, the National Natural Science Foundation of China, the Water Conservancy Pilot Study Program of the Ministry of Water Resources, the Special Funds for Scientific Research on Public Benefit of the Ministry of Water Resources to name a few. With these projects, key issues of the river after the TGP operation have been investigated and predicted, such as the flow kinematic characteristics, the propagation features of extreme floods, fluvial process and their impact on flood protection, water intakes along the river and the plan for river regulation works (Figures 4-6).

In addition to the above activities, the CRFPPM has also undertaken more than 100 various engineering research projects, such as the regulation of the navigation channel and bridge construction in the Changjiang River.

A number of high impact research findings have already been achieved through the implementation of these projects. Such findings have already been applied in the Comprehensive Plan of the Changjiang River Basin, the Plan for River Training of the Middle and Lower Reaches of the Changjiang River, the Master Plan of Follow-Up Work of the TGP, etc. The results have


Figure 4. Immovable bed model tests

also been adopted to guide the design and implementation of future river regulation works. The research results achieved during the verification stage of these hydraulic structure related projects (e.g. bridges, docks, water intakes and outlets) have not only been employed in the planning, design and construction of the projects, but more importantly also have provided the scientific basis and technological support for administrative licensing and management of the projects. During the period of 2008 to 2016, the research results achieved from the CRFPPM have been awarded more than 10 state, provincial or ministerial level prizes for progress in science and technology. Over 100 journal and conference papers have been published. Nearly 20 national patents have been authorized. More than 20 PhD or MSc students have graduated through various high impact research projects on the CRFPPM.

Figure 5. Movable bed model tests (with blue

Figure 6. Tests on the regulation of the navigation

Jinyou Lu is professor and president of the Changjiang River Scientific Research Institute (CRSRI), China. He graduated in river dynamics and river improvement from the Wuhan University of Hydraulic and Electrical Engineering in 1984, and obtained MSc in hydraulics and river dynamics from CRSRI in 1987. He is currently deputy director of the executive committee of IAHR China Chapter, deputy director of the Sediment Commission of the Chinese Hydraulic Engineering Society, member of the Expert Group on Sediment of the Three Gorges Project, and director of the Key Laboratory of River Regulation and Flood Control of the Ministry of Water Resources, China. His research focuses on motion of sediment and river flow, evolution and regulation of rivers and lakes, and sediment problems in water conservancy and hydropower projects.

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