Solid model test on Daijiazhou reach of administering project for improving the channel standard of the section of Yangtze River between Yichang and Anqing

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Abstract. Daijiazhou reach is located at the section of Yangtze River between Wuhan and Anqing, is important one of the shallow water channels in the middle reaches of Yangtze River. Through analysis of river evolution and the model test of river engineering, change rules of scouring and silting of riverbed, stability of beach, split ratio of branch and so on were studied focally after administering project for improving the channel standard was carried out, and the influence on river regime, flood control, slope stability and channel and so on was analyzed after the administering project was executed. The results show that the implementation of project management can achieve Daijiazhou reach straight channel 6.0m channel unobstructed, and has little effect on flood control and slope stability, split ratio of right branch of Daijiazhou increases larger, has a certain effect on the river regime. The results can be used for the management of engineering demonstration, design reference.

Introduction

The length of the section of Yangtze River between Yichang and Anqing is about 1037 km, there are lots of beaches and water is shallow, it had always been the focus and difficulty of flood control and channel construction for Yangtze River. In recent years, with the construction of the water channel with 12.5 m depth in Yangtze River following Nanjing and the formation of the upper reach of the Three Gorges Reservoir, the depth standard of shipping from Yichang to Anqing was obviously low with depth from 3.5 m to 4.5 m, it turned the bottleneck of the golden waterway of Yangtze River, thus it is very important to develop the research and construction on improving the standard treatment of the waterway of the section between Yichang and Anqing of Yangtze River. Daijiazhou reach is located at the section of Yangtze River between Wuhan and Anqing from Ezhou City to Huifengji, its length is about 34 km, it is important one of the shallow water channels in the middle reach of Yangtze River. The administering project for improving the channel standard of the section of Yangtze River between Yichang and Anqing planed that the bank of river section was heightened and ridge dams of the first phase project were stretched upward, fishbone was setup, beach protection, submerged dike, bottom protection were built [1].

The domestic research of Daijiazhou reach administering project in 2006, the regulation principle of 4.5 m navigation deep channel was put forward based on the evolution law of the river reach and the characteristics of navigation obstruction, and the research of engineering project is carried out, the overall control scheme, administering scheme of the first phase of project and guard scheme of lower right margin of Daijiazhou were respectively carried out [1]. Including natural flow characteristics, collapse characteristics and revetment measures of Daijiazhou reach were studied [2,3]; The evolution of Daijiazhou reach riverbed and navigation characteristics were analyzed, the scheme of right edge of revetment project was studied [4,5]; The evolution of the river channel in Ehuang and the countermeasures were discussed [6]; The protection scheme design and research on the regulation engineering of Daijiangzhou waterway were done, the research was limited to the protection of the 4.5 m navigation depth of the waterway safety, but for the navigation depth was 6.0 m and greater than 4.5m, the waterway safety for Daijiazhou reach was not studied, there were few studies on the improvement of channel standard treatment project at home and abroad [7,8].

The fixed bed and movable bed models are made based on the boundary condition of river bank and changes of scouring and silting over the years of Daijiazhou reach. Through the analysis of river evolution and river model test, the influence on river regime, flood control, slope stability and channel and so on will be studied after the administering projectwas executed, thus the rationality and influence rules of administering project for improving the channel standard of the section will be demonstrated.

Riverbed evolution and trend of Daijiazhou reach

The history of evolution

Daijiazhou reach is located at the uplift belt of fold of Daye (Fig.1), there was no significant change in the history of the channel based on the influence of the structure control. Daijiazhou today was formed in the late Qing Dynasty. According to records of the Qing Tongzhi “illustrated Yangtze River”, there were Zhoujiazhou, Daijiazhou, Bigazhou and Xinyuzhou between Xihuihou and Taizijia from the west of Huifengji. After the Qing Guangxu Dynasty, Zhoujiazhou shift down and kept connect with Daijiazhou, Bigazhou sank, Xinyuzhou turned alongside to marginal bank. The channel of the section was basically evolved to current bend river type with double branches, for nearly a hundred years, the riverbed plane shape change was not big, DaiJiazhou was basically stable [1].

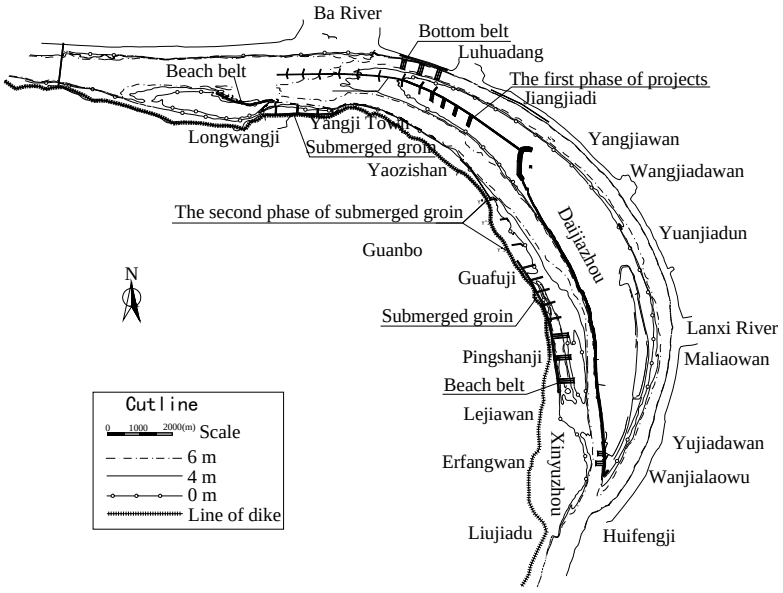

Fig. 1 Sketch map of the administering project of Daijiazhou reach

Recent evolution

The channel and shoreline of Daijiazhou were basically stable based on the influence of the controlling of node and the construction of revetment engineering. The evolution of riverbed was mainly in scouring and silting of riverbed, disappearance and growth of beach, rise and fall change of river inlet. In the whole, the head of Daijiazhou was shallow in beach and long in silt over the years, the split point of thalweg turned upwards lots of kilometres from Longwanji to the middle between Ehuang Yangtze River Bridge and Chihuqianzhou. The water flow entered respectively the left and right branches after the diversion of water, the change of erosion and deposition of riverbed of the left branch was smaller, thalweg was always stick to the shore, the nearest distance was about 30 m; the change of scouring and silting of riverbed of the right inlet was bigger, especially the scouring and silting of riverbed of the right edge of Daijiazhou changed frequently, the swing amplitude of thalweg was bigger, the nearest swing amplitude was about 800 m. At present, the right branch of Daijiazhou reach was main branch, the left branch was subordinating branch.

The plane position of Daijiazhou and Xinyuzhou was relatively stable, especially, the change of scouring and silting was very small in the past years. There were two deep grooves of Guafuji and

Huifengji in the Daijiazhou river section. Because the two boundary conditions were better, the plane shape and the position of the two deep grooves were relatively stable for many years.

Prediction of the evolution trend on water storage of the Three Gorges Reservoir

Because of the change of water and sediment conditions, after the Three Gorges Reservoir built, scouring along the channel of long distance will occur in the channel downstream of the dam. Because of the controlling of node and the construction of revetment engineering in the section, the original river bed boundary condition, river plane shape and river evolution laws will not have a big impact after Three Gorges reservoir turned to water storage and application, and Daijiazhou reach will continue to maintain a river pattern of "micro-bending and anabranched" [1].

The model test of river engineering

The design of the model

The test scope of fixed bed model for DaiJiazhou was from Ezhou at Huangzhou reach to Tujiaying at Huangshi reach, its length was about 40 km. The test scope of movable bed model was from Wuzhanggang to Lijiadawu, its length was about 34 km. The similar condition of model design included geometric similarity, similarity of flow movement and sediment movement similarity [2,3], the plane scale (α_L) was 400, the vertical scale (α_H) was 100, the model variable rate (η) was 4.0.

The model was mainly used to simulate suspended sediment movement. Through comparison and selection, a new type of composite plastic sand was used in the model developed by Yangtze River Academy of Sciences. The sand had the advantages of light weight, stable performance, good forming, it was close to the natural sediment particle morphology, its basic physical parameters were 1.38 t/m^3 in wet density, 0.65 t/m^3 in dry density. Based on Yangtze River flood control model design and the sand selection results of Yangtze River flood control model, the sand could meet mith the requirement of sediment model similarity, and real scale was shown in Table 1.

Table 1 The scale of river engineering model of the administering project of Daijiazhou reach

Similar condition	Scale name	Scale symbol	Scale value	Note
Similarity of geometric	Plane scale	α_L	400	(1) The density of composite plastic sand is 1.38 t/m^3. (2) The density of natural sand is 2.65 t/m^3. (3) The scales of sediment content scale and riverbed deformation time will be carried out through results of test.
	Vertical scale	α_H	100	
Similarity of flow movement	Flow speed scale	α_V	10	
	Roughness factor scale	α_n	1.08	
	Flux scale	α_Q	400000	
	Flow time scale	α_t	40	
Similarity of sediment movement	Starting velocity scale	α_{V_0}	10	
	Grain diameter scale	α_d	0.85	
	Settling velocity scale	α_ω	2.50	
	Sediment content scale	α_s	0.442	
	Riverbed deformation time scale	α_{t_2}	183	

The condition of the model test

(1) The boundary condition of the test

The movable bed model was reformed from the model with fixed bed. Based on the boundary condition of river bank and changes of scouring and silting over the years of the river section about the model, the riverbed elevation about 20 m was used for fixed bed in principle, and the local bank revetment and thalweg below 20 m elevation was still the range of fixed bed, the rest was movable bed groove, thus it could reflect river regime and change characteristics of scouring and silting upstream and downstream the project. Moreover, based on the situation of administering for project

river course and channel, these projects were stimulated such as the first phase projects of administering channel for Daijiazhou, the lower right margin of the guardian project and the second phase of project for Daijiazhou in the middle of Yangtze River.

(2) The water and sand condition of the test

The Three Gorges Project had been completed and operated, The condition of incoming water and sediment for Daijiazhou reach compared before the construction had undergone great changes, the actual runoff and sediment conditions after the operation of Three Gorges Project was fully considered in the experimental study, and the test series year of test was confirmed as such year: 2008, 2009, 2010, 2011, 2012, the typical hydrological years of runoff and sediment process was generalized as shown in Fig. 2. In the model, the terrain in February 2014 as the initial terrain, contrast tests were respectively carried out with and without the project, through the contrast test to eliminate the influence of the scouring and silting of natural channel and important wading structures. After implementation of channel regulation project for Daijiazhou reach, the influence of river regime, flood control, shipping and others could be considered based on single factor.

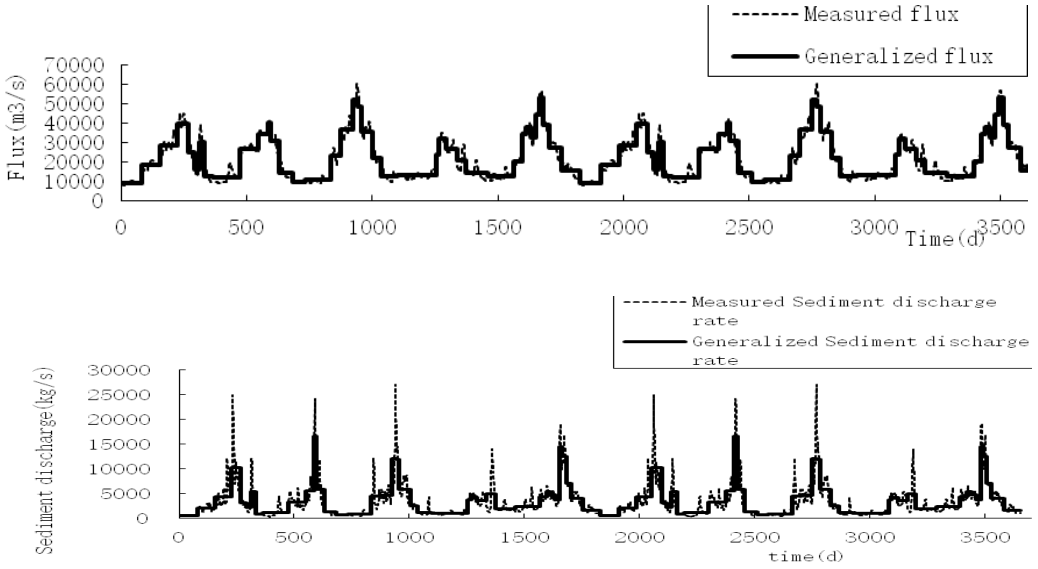

Fig. 2 Generalized figure of the typical hydrological years for incoming water and sediment process

Results of test

Results analysis of movable bed model before engineering implementation

(1) The change of plane

The test results of movable bed model before the implementation for improving the standard management of channel engineering show that the overall river regime of Daijiazhou reach changes little while pouring the water into the model to the end of tenth year, and the location of the main flow line and thalweg change little, but the local adjusts. The channel of Ba River is a straight form, the main line in the middle of a slight swings slightly left, the left branch of circular channel maintains micro bending shape, the main flow line near the left bank swings small; The right branch line from the mainstream straight channel gradually turns toward the left bank from Yanji, and it swings to the right edge of the left bank of Daijiazhou.

(2) The change of scouring and silting of riverbed

The river regime of Daijiazhou reach keeps basically consistent as the initial terrain at the end of fifth year, tenth year, the change characteristics of the river channel are alternate from scouring to silting, it keeps scouring in the main, silting is mainly concentrated in the shallow waterway of transition zone from the channel of Ba River to the straight channel of Daijiazhou, and the main ship channel of the left trough in the middle and lower section of straight channel.

The amount of cumulative scouring test reaches 102320000 m^3 at the end of fifth year, including the amount of the channel of Ba River (Wuzhanggan-Ba River) is 27600000 m^3, the amount of the channel of Daijiazhou (Ba River-Lijiadawu) is 74720000 m^3. At the end of tenth year, the amount of cumulative scouring test reaches 166260000 m^3, including the amount of the channel of Ba River is 44840000 m^3, the amount of the channel of Daijiazhou is 121420000 m^3.

Results analysis of movable bed model after engineering implementation

(1)The change of plane

The test results of movable bed model after the implementation show that the overall river regime of Daijiazhou keeps relatively stable while pouring the water into the model to the end of tenth year, and the location of main flow line and thalweg change little, but the local adjusts. Including the main flow line of Ba River swings from center left to center,

The main flow line of middle and lower section for the right branch straight channel of Daijiazhou greatly swings to right branch and left trough, and other location of main flow lines and thalweg changes little.

Compared with the previous program, The model runs to the end of tenth year, The 15 m and 10 m contours of Ba River change little, the contour near 5 m of the beach of Chihu keeps continually the trend to the right bank, and the trough body keeps further widening; the contour near 0m of the beach of Chihu keeps atrophy and downward movement, it keeps down and its distance is about 450 m. The contour of depth of transition zone 6.0 m from Ba River channel to the straight channel is through, the minimum width is about 230 m; The contour of depth of upwards and shallow zone 6.0 m at the middle of straight channel is through, the minimum width is about 245 m; The contour of depth of downwards and shallow zone 6.0 m at outlet is through, the minimum width is about 460 m, the 6.0 m channel of the straight channel keeps basically unobstructed.

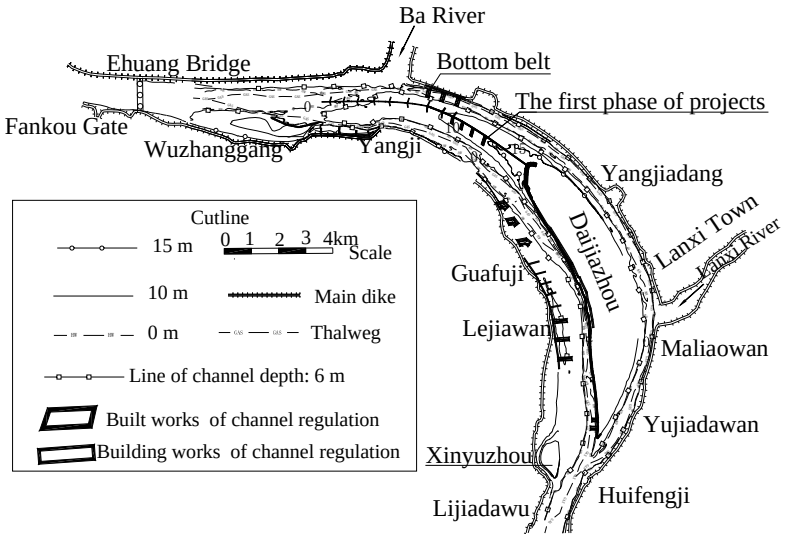

Fig. 3 The terrain change of the model with movable bed after engineering implementation at the tenth year

(2) The change of scouring and silting of riverbed

At the end of fifth year, the amount of cumulative scouring of the test section reaches 101070000m^3, including the amount of the channel of Ba River is 27250000 m^3, the amount of the channel of Daijiazhou is 73820000 m^3. At the end of tenth year, the amount of cumulative scouring of the test section reaches 164250000 m^3, including the amount of the channel of Ba River is 44300000 m^3, the amount of the channel of Daijiazhou is 119950000 m^3. In the whole, the scouring to silting of Daijiazhou channel keeps alternate at the end of fifth year, tenth year, It is in scouring at the shallow zone of the inlet for the straight channel of Daijiazhou, silting at the right trough near submerged dam project in the middle and lower section of straight channel, scouring at the left groove, silting at the zone of the ridge dam and the thorn dam of two sides of Daijiazhou.

(3) The change of split ratio of branch

The implementation of the Daijiazhou project, the split ratio of branch may have a certain impact. the split ratio of branch increased slightly after the implementation of the project, including the diversion ratio increases from 62.20% to 63.30% before the end of fifth year when the flux is 14665 m^3/s, it increases by about 1.1%; The split ratio increases from 61.50% to 64.40% before the end of tenth year, it increases by about 2.9%. After the implementation of the project, the main reasons for the increasing of split ratio of right branch of Daijiazhou are under the action of the project such as the ridge dam and the thorn dam of two sides and submerged dam and beach belt built at right lower reaches of straight channel of Daijiazhou, some zones are scoured such as the right branch of straight channel import shallow region, the middle and lower section of straight channel. It is favorable to improve the navigation condition of straight channel, but it has a certain effect on the river regime as shown in Table 2.

Table 2 The change of split ratio of Daijiazhou branches before and after project implementation

Status of implementation of project	Name of branch channel	The end of the fifth year	The end of the tenth year
Without implementation of project	Right branch	62.20%	61.50%
	left branch	37.80%	38.50%
With implementation of project	Right branch	63.30%	64.40%
	left branch	36.70%	35.60%

(4) The change of water level

Test results of the model with movable bed show that the water level of Daijiazhou reach decreases to some extent under low flow by the influence of channel regulation project of Daijiazhou, when the flux of Wuhanguan is 14665 m^3/s, the water level near Longwanji decreases most, the value decreases about 0.06 m. When the flux of Wuhanguan is 53317 m^3/s, the water level of Daijiazhou reach increases to a certain degree, the water level elevation largest is at Guafuji, the value of water level elevation increases about 0.04 m.

(5) The change of flow velocity

Test results of the model with movable bed show that the flow velocity is effected by 4 submerged groins deflecting at marginal bank of the upper right bank of Longwanji, the flow velocity near the left bank of the section of Longwanji increases in the main, the flow velocity near the right bank reduces to a certain extent. Under low flow velocity (The flux is 14665 m^3/s), the maximal flow velocity near the left bank increases by 0.09 m/s, the maximal increasing value of flow velocity is at the middle of the channel, the value is 0.15 m/s, but the maximal decreasing value of flow velocity near right bank is 0.13 m/s; The change range of flow direction near the left bank is less, generally in 1-2 degrees, and the change range of flow direction near the left bank is less, generally in 1-3 degrees, the largest amplitude is located at the project.

Conclusions

(1) In recent decades, under the action of natural node control and artificial revetment for Daijiazhou reach, river regime reached basically stable, beach changed smaller. The application of the Three Gorges Reservoir had not huge effect on the evolution law of the river channel, Daijiazhou reach would continue to maintain a river pattern of “micro-bending and anabranched”.

(2) When the control project is not implemented, under the action of water and sediment in series, the change characteristics of the river channel alternate from scouring to silting, generally in the main scouring, silting focuses mainly at the shallow zone of transition section from Ba River channel to Daijiazhou straight channel, and the main ship channel of left trough in the middle and

lower section of straight channel, the water depth can not meet the requirements of 6.0 m navigation depth.

(3) After the implementation of the project, the riverbed of Daijiazhou reach behaves scouring and downcutting mainly under the action of water and sediment in series. Comparing with the status before the implementation of the project, the scouring amplitude of the river reach is slightly decreased. Under the influencing of the project, the river regime of Daijiazhou reach adjusts certainly. Under the action of the project such as the ridge dam and the thorn dam of two sides and submerged dam and beach belt built at right lower reaches of straight channel of Daijiazhou. Scouring is realized at the shallow zone of inlet of straight channel of the right branch, the middle and lower section of straight channel, diversion ratio increases. It is advantageous to improve the channel condition of the straight channel after the implementation of the control project, but there is a certain impact on the river regime.

(4) Before and after the implementation of the control project, the results show that the maximal backwater height in the lower section of the right branch of Daijiazhou is 0.04 m under flood flux (53317 m^3/s), it has little effect on the flood control of the river reach after the implementation of the project.

(5) After the implementation of the standard control project of the channel, the import navigation channel of Daijiazhou straight channel keeps through, the middle and lower section of navigation channel changes wide, it has improved the navigation conditions to a certain extent, it can achieve unobstructed basically in navigation channel for straight channel with depth of 6.0 m.

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