EXPERIMENTAL STUDY ON THE LAYOUT AND RIVER REGIME OF THE INTAKE OF WATER ENVIRONMENT COMPENSATING PROJECT FROM YANGTZE RIVER TO HANJIANG RIVER ABOUT SOUTH TO NORTH WATER TRANSFER

Hui ZHANG[1] *Ligang LI*[1] *Huazhong SHEN*[2]

River Research Department, Yangtze River Scientific Research Institute, Wuhan, 430010, China.,

River Affairs Bureau, Changjiang Water Resources Commission, Wuhan, 430010, China.,

1,E–mail: zhangh314@126.com

1,E–mail: llglq@yahoo.com.cn

2,E–mail: shenhz@cjw.com.cn

Abstract: After Danjiangkou project heightened and midline project about South to North Water Transfer put in practice, water flux will be decreased from lower Xinglong reach of Han River, thus it will lead to negative impacts to water environment. To improve shipping, ecology, water supply of towns, agricultural irrigation, and the ecological environment protection of the lower Han River, water environment compensating project will be built, water will be diverted from Jingjiang reach of Yangtze River to lower Xinglong reach of Han River and the project acts as one of the four harness projects of the Middle Route Project of the South to North Water Transfer.

The intake of the project will be built at the site from Juzhang estuary of Longzhouyuan reach in Upper Jingjiang stretch of downstream of the Three Gorges Project in Yangtze River to 3.34km. Through the whole and the local river engineering model experiment, the effects of river course evolution of the intake reach on the water intake after the operation of the Three Gorges Project are studied.

Moreover, influences of the project layout on the river regime of intake reach, water level, flow velocity and flow pattern are established. Finally, the effects of energy dissipation complexion of stilling basin of intake gate, engineering effect of sediment pool and snail-preventing of snail settled pool and so on are studied. It shows that the results can be adopted to or referenced to designing project.

Key words: water environment compensating, intake; model experiment, river regime,layout

1. Introduction

Diversion project from Yangtze River to Hanjiang River is a Super-large main canal, and also is one of the four harness projects of Middle Route Project about South to North Water Transfer. The intake flux of design of the channel is 350m^3/s and the maximal intake flux of design is 500m^3/s. With the project, water will be draught from Jingjiang River reach of Yangtze River to lower Xinglong reach of Han River. Moreover, negative impacts of water quantity decreased about lower Xinglong reach of Hanjiang River can be reduced, and water environment of the river section can be improved as well as condition of water supply of towns and agricultural irrigation can be reformed.

From the intake of Huojianzhou (Jing 25) to the exit of Xinsanbatan (Jing 46) at upper Jingjiang reach of middle Yangtze River, the river section of intake of the project is about 40km, and it consists of curve and furcated reachs of Wangshi and Shashi. The head of intake channel is located at the left bank of the straight transition section between the south river bend of Wangshi and the north of Shashi, and it is about 3.3km from Juzhang estuary, and the intake section of channel is about 4.0km.Through the whole and the local river engineering model experiment, not only rules of river course evolution of riverway of intake reach after storage of Three Gorges Project and use but also the impacts of diversion of flow on water draught are studied. Moreover, changes about river regime of riverway of intake reach, water level, flow velocity and flow pattern come from project collocation are established. Finally, the effects of energy dissipation complexion of stilling basin of intake gate, engineering effect of sediment pool and snail-preventing of snail settled pool and so on are studied.

2. Design of river engineering model

The whole river engineering model includes rigid bed model and movable bed models. According to research task and condition of flow and sediment, the maximum possible influence area of upper and lower river hydrology condition and river regime coming from scheme of intake flux considered, the simulation scope of rigid bed model is conformed from the intake of Huojianzhou (Jing 25) to Yangeryueji (Jing 47) is established, it is about 45km. And the scope of movable bed model is conformed from the exit of Huojianzhou to the conflux intake of Sanbatan is established, the effective survey scope is from the intake of Mayangzhou (CS320) to the exit of Sanbatan(CS436), its length is about 26km(Figure 1).

The local river engineering model of diversion canal consists of clear-water model test and sediment model test. The scope of intake channel model is conformed from intake section to the end of the intake around in Yangtze river, and it is composed of intake channel of the front of gate, intake gate, desilting basin and snail settled pool, pumping station of lifting water, controlling gate of pumping station, and its upper and lower channel, gate of preventing flood of dike in Jingjiang River and so on., and it is 3.1km in length(Figure 2).

The resemble condition of rigid bed model design involves in similitude of geometry, current movement, and the model of movable bed also includes similitude of sediment movement (table 1).

Fig.1 Collocation of whole river engineering model

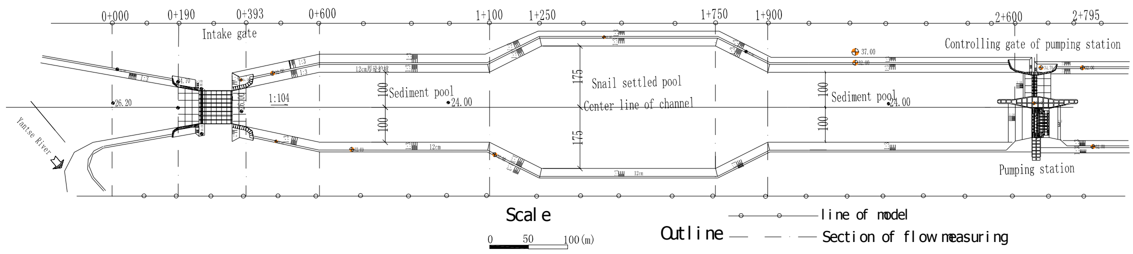

Fig.2 Collocation of local river engineering model of intake channel project

Table 1 Scale relation of the model

Item	Name of scale	Expression of scale	Value of scale			
			Whole rigid bed	Whole movable bed	Clear-water model test	Sediment model test
Similitude of geometry	Scale of plane	α_L	450	400	80	80
	Scale of uprightness	α_h	100	100	80	80
Similitude of Flow movement	Scale of velocity	α_v	10	10	8.94	8.94
	Scale of coarse ratio	α_n	1.02	1.08	2.08	2.08
	Scale of flux	α_Q	450000	450000	57243	57243
Similitude of suspension load movement	Scale of sink velocity	α_ω		2.22		8.94
	Scale of grain size	α_d		0.91		0.52
	Scale of stirring-up velocity	α_{v_0}		≈10		8.94
	Scale of sediment concentration	α_s		0.48		0.08
	Scale of dry bulk density	$\alpha_{\gamma 0}$		2.62		2.17
	Scale of erosion-depositio	α_{t2}		203		218
Similitude of bed load movement	Scale of sink velocity	α_ω		2.22		
	Scale of grain size	α_d		0.75		
	Scale of threshold velocity	α_{vo}		≈110		
	Scale of transport sand of single width	α_{qb}		481		
	Scale of dry bulk density	$\alpha_{\gamma 0}$		2.74		

3. Test condition and model verification

3.1 Test condition of water and sediment

(1) Whole river engineering model

Test of the rigid bed model is carried out under four hydrology conditions such as safe flux of upper Jingjiang River, bed-forming discharge of Shashi reach, maximum navigable discharge, minimum navigable discharge (Table 2). The results of one-dimensional sediment scour and silting model which conformed from Yichang to the reach of Datong as the controlling condition of intake and exit are used about the test of movable bed model, and the test conditions of runoff and sand transportation such as water level, flux, sediment concentration and distributary flux of Taipingkou are generalized from the results. Because of lack of runoff and sand transportation conditions in the first year of series years, the second year of mathematic model as the first year of model test, and the test process is 19 years.

Table 2 The hydrology condition of the whole rigid bed model test

Flux	The flux of Shashi(m^3/s)	Distributary flux of Taipingkou (m^3/s)	Water level of Shashi (Yellow Sea altitude ,m)
Safe flux of upper Jingjiang River	50000	3150	42.62
Bed-forming discharge of Shashi reach	27000	1500	38.94
Maximum navigable discharge of Shashi reach	40800	2500	40.79
Minimum navigable discharge of Shashi reach	5500	0	29.88

（2）Local river engineering model

Test of the clear-water model is carried out under three hydrology conditions such as the maximal intake flux, intake flux of design, the maximal intake water level (dominating work of eliminating energy design) (Table 3). Based on observation and numeration analysis, the maximal and the hypo-maximal of the average annual sediment concentration are in the first year (2003) and in the fifth year after sluice of the Three Gorges reservoir, and those have huge impact on accretion of sediment of project. According to intention of the test, the test of sediment model test adopts measure value or simulation value of water level and sediment concentration which are the values of the first year (2003) and the fiftieth year of typical series years after storage, and the flux of month and ten days about design level year is used about flux.

Table 3 Hydrology condition of clear-water model test

No	Flux of intake /m^3/s	Water level before gate (Yellow Sea altitude)/m	Work	Remark
1	350	32.82	Intake flux of design	/
2	500	34.80	The maximal intake flux of design	/
3	500	40.20	The tiptop intake water level (dominating work of energy dissipation design)	The number of holes: 2,4,6,8

3.2 Model verification

In the test of whole rigid bed model, water surface profile, the velocity of flow and the ratio of distributary flux are verified by hydrology material in 2003. In the whole movable bed model, initial relief map is made by measure channel relief map(1/10000) in Oct,2002, and measure landform is adopts to final relief map in Aug,2004. In order to reappear measure landform, the natural process (from Oct,2002 to Aug,2004) of runoff and sand transportation simulated in the model. In the test of local river engineering model, water surface profile is verified under three kinds of fluxs such as the maximal intake flux of design 500m^3/s, intake flux of design 350m^3/s, and raising water flux 430m^3/s.

The test of model verification shows that whole rigid bed model is basically similar to prototype on the aspect of water surface profile, distribution of flow velocity and the ratio of Sanbatan south and north distributary flux. According to reach observation, whole movable bed is similar to prototype on the aspect of the character of sediment scour and silting, the vertical and horizontal distribution of sand beach. Local model resembles basically prototype on the aspect of water surface profile, thus the results of model verification keep accord with the demand of test regulations of river engineering model.

4. Results of experiment

4.1 Whole model of rigid bed

(1) The change of water level before and after the project

When the Intake angle respectively is 30^0, 50^0, 60^0, the experiment shows that the Intake angle the influence rule is not obvious to the water level, but the size of Yangtze River flux and intake flux reduces the water level value disciplinary and obviously. Generally, water level reduces obviously at the intake nearby, and changes little relatively far away at the intake. When Yangtze River flux is 5500m^3/s, the effect of intake flux is the most, with intake flux 500m^3/s, the water level of river section from Jing 28 to ErLangji decreases to 0.15~0.38m. with intake flux 150m^3/s, the water level of river decreases to 0.05~0.17m(Table 4).

Table 4. When Yangtze River current capacity Q=5500m^3/s each pilot plan implementation water level drop value Unit: m

Station Name	Intake flus 150m^3/s			Intake flus 300m^3/s			Intake flus 500m^3/s		
	Angle 30°	Angle 50°	Angle 60°	Angle 30°	Angle 50°	Angle 60°	Angle 30°	Angle 50°	Angle 60°
Jing 28	0.05	0.05	0.06	0.13	0.13	0.12	0.15	0.15	0.16
Jing 30	0.08	0.08	0.10	0.20	0.17	0.19	0.33	0.22	0.34
Jing 31	0.17	0.07	0.18	0.27	0.16	0.25	0.36	0.22	0.38
Erlangji	0.10	0.09	0.13	0.21	0.16	0.18	0.31	0.21	0.32

（2）The change of flow Velocity before and after the project

When Q is 5500m^3/s, the influence of flow direction of intake water is obvious at section 5~7, and the section 7 is biggest. The intake flux is bigger, effect on direction is bigger, and the distance is nearer, effect on direction is bigger. To the 6th section near bank 28m (start point distance is 120m), when 500m^3/s intake flux, flows towards left 54 degrees, effect on direction of intake flux disappears basically near shore 268~328m, the effect on direction of intake flux is about within 9 degrees about 3rd and 8th cross section.

To the effect on flow speed of intake

water, the 5th~8th cross sections is obvious, the speed of flow increases above the intake, the speed of flow reduces below the intake, and the influence to left half river is bigger than right half river. To the 6th cross sections far from the near shore 28m, when occupies the intake flux respectively is 150m^3/s, 300m^3/s and 500m^3/s, the speed of flow increases 0.19m/s, 0.44m/s, 0.75m/s, the speed of flow change is not obvious to far from the near shore 268~328m outside. When the intake flux are 500m^3/s of the 3rd section, the left half river speed of flow increases, the scope is 0.02m/s~0.2m/s. The 8th cross section speed of flow reduces, the scope is 0.03m/s~0.28m/s.

When Yangtze River flux is 27000m^3/s and 40800m^3/s and intake flux is 500m^3/s, the analysis of flow speed shows that the 6th cross section near bank speed and direction of flow changes obviously, and other cross section changes not obviously.

（3）The change of distributary ratio of San Ba Beach

Distributary ratio of former and latter of intake water about section 10 shows that distributary ratio of the left is 26.3%, 25.5%,25.7%, 26.2% respectively before the intake water and when the flux of intake water is 150m^3/s, 300m^3/s, and 500m^3/s, and it is within the error field of measure, thus it leads to not influence on the intake water of distributary ratio about SANBA beach.

4.2 Whole model of movable bed

（1）Terrain experiment

The movable bed research indicates that the washes out of intake section of river to the maximum value in the 11th year's end, the entire section of river washes out 46,000,000 m^3 and in the 14th year's end has siltation. The wash out of basic succession is consistent of the Ma Yangzhou, Tai Pingkou, San Ba and so on of 3 parts of river. To the 11th year's end, the Ma Yangzhou section of river flushes deep 1.05m equally, the Tai Pingkou section of river flushes deep 1.69 m equally, the San Ba beaches flush deep 0.72m equally, the section of river width compared to change deeply small.

Looked from the river potential, the main change in Tai Pingkou canal, original double trough and right trough for main channel pattern gradually to double trough left trough into main channel pattern transformation, 5~11 year's end the center of beach causes the elevation as a result of the section of river large washout to reduce with the reduction of area, silts up high, the area to 14 year's end along with the river course backsilting the center of beach expands, section of river width deep ratio fill-out. the Sanba beach reduction of area, because between the Tai Pingkou canal and the San Ba beach right branches becomes the interrupted trench group, the San Ba beach left branches wither, right branch development. The Mayangzhou section of river overall river potential change is not big, the right branch primarily at the end of pattern has any change.

（2）Sediment concentration test

During dry season, the starting main transport sand belt of the north and south trough of Tai Pingkou in the northern trough in the river course washout process (to 11th year), the starting main transport sand belt move to gradually to the south trough, but (11 years to 19 years) the starting main transport sand belt to bring back to the northern trough in the riverbed siltation process; During normal water period and flood period the north trough overall silt content reduces relatively. In the Sanba beach, north and south branch silt content change rule is not obvious(Table 5).

Table 5. Sediment concentration distribution Unit: kg/m^3

Series year	Current capacity (m^3/s)	Ma Yangzhou imports	North trough of Tai Pingkou	South trough of Tai Pingkou	North San Ba beaches branch	South San Ba beaches branch
1st year	5411	0.27	0.11	0.06	0.16	0.22
1st year	27346	0.04	0.26	0.21	0.09	0.05
1st year	15326	0.1	0.12	0.08	0.28	0.1
5th year	5449	0.11	0.13	0.27		0.07
5th year	31138	0.09	0.06	0.24	0.04	0.15
11th year	26082		0.17	0.15	0.24	0.13
11th year	10504		0.08	0.07	0.04	0.07
12th year	5784	0.13	0.17	0.09	0.03	0.16
14th year	16679	0.12	0.19	0.2	0.06	0.1
14th year	26303	0.08	0.14	0.06	0.25	0.18
15th year	5999		0.32	0.21	0.57	0.59
19th year	25926		0.06	0.15	0.09	0.16
19th year	17115	0.12	0.17	0.14	0.16	0.07

4.3 Local clear-water model

（1）intake sluice flow regime

It is tranquil in water surface in upper sluice chamber and smooth in entering flow. Only in the work of energy-dissipation, as a result of the side contraction influence, in front of two side holes has the funnel shape whirlpool formation. Under any works, the current of water in the lock chamber is steady.

The flow regime of sluice downstream is related with flow flux, water level of outer river and gate opening way. In the case of design maximum intake flux and design intake flux, when the sluice gate hole opens wide releases flows, under the sluice gate formed submerged flow and there is no hydraulic jump in the stilling pool. In the case of energy expending, the sluice opens 8 gates (all open) and among 6, there is has hydraulic jump and the head of hydraulic jump in the sluice chamber. Among when the sluice opening 4 gates, there is stable hydraulic jump in the stilling pool pitch, the jump connected with the tail-water is quite well, there has partial backflow in the left bank of the downstream settling basin entrance sections. Among when the sluice opening 2 gates, produces hydraulic jump, the head of the jump is far from the downstream (0+600), nearby the downstream settling basin around the right bank has wide range backflow.

（2）flow velocity of intake sluice

Looking from the velocity of flow distribution, the velocity of flow that approaching upstream sluice chamber cross section (station number 0+190) is bigger than the flow far away from the sluice chamber cross section (station number 0+000). Looking from the vertical average velocity, the right bank is bigger than the left bank, the mainstream deviates right bank and the water surface speed of flow is bigger than the base speed of flow. In the case of energy dissipater, 0.36～0.37m/s. In the case of design maximum pilot current capacity and design intake current capacity, the vertical average velocity of stream maximum value is 0.63～0.68m/s, the base maximum Velocity value is 0.59～0.64m/s.

The velocity of flow distribution of sluice downstream is related with flow current, provinces water level and gate opening way. The experimental material indicated that in the case of energy dissipater, the end of the anti-impact apron after stilling pool the speed of flow still quite big. When the sluice opens 2, 4, 6 and 8 gates, the vertical average velocity of stream maximum value respectively is 5.03m/s, 2.98m/s, 2.02 m/s and 1.78m/s. In the case of design maximum pilot current capacity and design intake current capacity, the end of the anti-impact apron after stilling pool the speed of flow decreased. The vertical average velocity of stream maximum value respectively is 0.97 m/s and 0.71m/s.

4.4 Local sediment model test

（1）Sediment siltation test

After the sediment-laden flow enters the diversion canal settling basin, the coarser particles silt first deposited nearby the settling basin entrance, the finer silt deposited middle of the settling basin and the tail tribe silt, but extremely fine-grain silt because of not fluent alluvium strength limit along with fluent overflow settling basin outside. Above the 1+100 cross sections is similar to the Delta siltation shape, the silting-up rate is big and the particle size is thick, the following silting-up rate few also the particle size is thin, the silt deposit pitch diameter is not big along the regulation change, also along with the time passage, the Delta siltation apex unceasingly will advance to the settling basin rear part.

The diversion canal settling basin has certainly sinks the sand effect, in all levels of current capacity situation, the entrance silt content is bigger, the silt content weakens along the regulation really, specially above the station number 1+100 cross sections, the silt content is quick decay along the cannel path. The Following silt content change slowly along cannel path. When 1st level of current capacity, the silt content of the exports occupy 39.93% of the enter of pond cross section. When 6th level of current capacity, the silt content of the exports occupy 62.67% of the enter of pond cross section. When 9th level of current capacity, the silt content of the exports occupy 89.86% of the enter of pond cross section, but under the influence of silts up, in front of the latter level relative flow the level current capacity sinks the sand efficiency to reduce.

The experiment indicated that, the settling basin in the movement process, along with the time passage, sinks the sand efficiency to reduce, the siltation is obvious.

（2）Snail siltation test

When uses the design proposal, in the case of the design pilot current capacity, the stream vertical average velocity of the sinks screw is smaller than 0.12m/s, satisfied the sinks screw's request. When the current capacity of the turbid water model reaches 455m^3/s and the clear water model design maximum pilot current capacity (500m^3/s), the cross section vertical average velocity of stream is bigger than 0.2m/s, can’t satisfied the sinks screw’s request.

5. Conclusions

(1) After building of Three Gorges project, changes about overall river regime of Mayangzhou reach are not too much, original double trough and right trough for main channel pattern gradually to double trough left trough into main channel pattern transformation, the area of Sanbatan reach reduces, the left furcated reach of Sanbatan shrinks, and the right furcated reach grows, river regime of project reach is propitious to intake collocation.

(2) The influence of diversion water angle to water level is not obvious, but the influence of Yantse River flux and intake flux have some rules and it is obvious, the possible maximal drop value of water river which comes from the influence of diversion

water nearby the intake, the value is 0.38m. The intake flux is more, the influence to the flow direction is bigger. And the distance to the intake is shorter, the influence to the flow direction is bigger. Diversion water cause to the increase of flow velocity of the intake upwards, and the decrease of flow velocity of the intake downwards, the influence in left river is bigger than right river. The ratio of distributary flux of Sanbatan is not influenced basically by diversion water. After diversion water, the flow velocity of intake upper channel and the deviation of flow direction nearby intake beacame bigger, thus strengthening guard on left bank of Taipingkou channel intake upwards to Juzhang river is advised.

(3) Under the works of maximal intake flux, intake flux of design, gate holes discharge openly, submerge flow is under gate. Under the work of energy dissipation, when 2 holes of gate are locally opened, far-forth hydraulic jump can be formed, the energy dissipation effect of hydraulic jump is bad, and the velocity is huge at the end of apron, the instance of erode is bad, thus local turning on should be avoid with operation.

(4) Desilting basin of diversion canal do some work, Under all levels flux, with increase of sediment concentration of intake, increase of sediment concentration attenuated along route, especially above the stake 1+100 cross sections, attenuation of sediment concentration changes more. During movement process of desilting basin, along with time change, the efficiency of sediment will decrease, alluvial effect is obvious. Thus proper measures are advised to improve sediment effect.

(5) Under the works of intake flux of design, snail settled pool can be satisfied with the demand of snail settled. When the flux is $455m^3/s$, the demand of snail settled can not be satisfied, thus subordinate equipments such as gather snail dyke, unstable dam are advised to effectively prevent snail from diffusing.

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