The numerical simulation study and application of transverse sediment and discharge dispatching of Gezhouba Project

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Abstract: It is of great significance to dispatch sediment and discharge by using hydraulic structures in water conservancy project. There are two methods for Sediment and discharge dispatching, transverse and longitudinal. The longitudinal dispatching is not effective for run-off-river power station or hydropower project with relatively small storage capacity; and it is important to dispatch sediment and discharge by the method of transverse dispatching through hydropower structures. In the thesis, the author researches the feasibility of dispatching sediment and discharge by numerical simulation aimed at decreasing navigation deposition and coarse sediment passing hydroturbine in Dajiang navigation Channel of the Gezhouba Project on the Yangtze River.

Key words: Gezhouba Project Sediment and discharge dispatching Transverse dispatching

1、 INTRODUTION

Gezhouba Project is an important constituent of the Three Gorges Project. The mean annual flow is 14300m^3/s，transport capacity of the average annual suspended sediment is 526 million t, the average annual sediment concentration is 1.19kg/ m^3 .

The total length of the dam of the Gezhouba Project is 2606.5m. The Er Jiang channel is arranged in the center of the whole project, with Da Jiang and Er Jiang power plant locates on both sides, the Da Jiang and San Jiang approach channel situates on each bank of the riverbed. The problem that coarse sand is inevitable to go through the turbines exists for a long time since the operation of the project. The size of the sediment concentration and the coarse sand is depended on the flow and sedimentation coming from the upstream, the location of the units and the application of the sediment flushing.The arrangement plan of junction is showed Fig1.

Fig1 Diagrammatic sketch about the arrangement of junction

As the Geahouba Project is a kind of run-of –river power station with the ratio of the

storage capacity to runoff is 3% approximately, thus its ability to adjust sediment flushing in the direction of longitudinal is quite limited. Under the condition that the structures along the dam axis is densely arranged, to decrease the coarse sand passing through the turbine, in addition to discharging sediment by making full use of the existing hydropower structures, it is also advantageous to reduce the coarse sand passing through the turbine and the abrasion of the units by guiding the direction of the sediment and discharge by the method of transverse dispatching by making full use of the flood discharging sluices of the Er Jiang channel and the sediment sluice of the Da Jiang Channel.

The article has established the plane two-dimensional mathematical model based on the actual situation of Gezhouba Project, the model has been validated by the actual data of Gezhouba Project. Under the basic condition above mentioned, the model has been applied to optimized transverse dispatching of sediment of the Gezhouba Project.

2、THE ESTABLISH OF 2-D NUMERICAL MODEL

2.1 MAIN EQUATIONS

2-D sediment numerical model is based on the following equations

Continuity and motion equations of flow:

$$\frac{\partial z}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0 \qquad M=hu \qquad N=hv \tag{1}$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+g\frac{\partial z}{\partial x}+g\frac{u\sqrt{u^2+v^2}}{C^2h}-\gamma_t\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)=0 \tag{2}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+g\frac{\partial z}{\partial y}+g\frac{v\sqrt{u^2+v^2}}{C^2h}-\gamma_t\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)=0 \tag{3}$$

Continuity equation of suspend sediment:

$$\frac{\partial hs_k}{\partial t}+\frac{\partial Ms_k}{\partial x}+\frac{\partial Ns_k}{\partial y}-\varepsilon\left(\frac{\partial^2 hs_k}{\partial x^2}+\frac{\partial^2 hs_k}{\partial y^2}\right) =-\alpha\omega(s_k-s_{*k}) \tag{4}$$

Riverbed deformation equation:

$$\gamma'\frac{\partial Z_b}{\partial t}=\sum_{k=1}^{ksk}\alpha\omega_k\left(s_k-s_{*k}\right) \tag{5}$$

Suspend sediment composition equation of riverbed:

$$\gamma'\frac{\partial(E_mP_k)}{\partial t}-\alpha_k\omega_k(s_k-s_{*k})+ \gamma'\varepsilon_1[\varepsilon_2P_{0k}+(1-\varepsilon_2)P_k](\frac{\partial Z_b}{\partial t}-\frac{\partial E_m}{\partial t})=0 \tag{6}$$

Where, C ～ Chezy coefficient; E_m ～ depth of mixture layer; h～depth; ksk ～ number of suspend groups; n ～ Manning roughness; P_k ～sediment composition of mixture layer; P_{0k} ～ natural bed sediment composition; s_k ～ sediment concentration of kth group; s_{*k} ～ sediment transport capacity of kth group; u、v ～ velocity in x, y

direction; z～ water level; Z_b ～riverbed altitude; α ～ recover parameter; ε～ sediment diffuse parameter; $\varepsilon_1,\varepsilon_2$ ～ signs; γ' ～ dry specific gravity of sediment; γ_t～ chaos viscous parameter; ω_k～ sediment settling velocity.

2.2 The verification of the model

The model is verified by applying measured value of Gezhouba Project. The results indicate that:(1) the calculation value of velocity and direction is well matched with measured value, (2) the calculation value of sediment concentration is consistent with measured value, (3) the amount of erosion and deposition is verified, and calculation error is below 20%.

The model preferably simulates flow sediment movement to some degree, which indicate this model can be applied into the implementation scheme study of the sediment transverse dispatching of the Gezhouba Project.

3 OPTIMIZATION ON SEDIMENT AND DISCHARGE TRANSVERSE DISPATCHING OF THE GEZHOUBA PROJECT

3.1 **Determination of dispatching principle**

It is shown by field data that sediment passing through Er Jiang is small and thin while that of Da Jiang is big and thick. It is mainly due to the curve current of the water flow in Nanjinguan. Therefore, in order to reducing the coarse sand passing through turbines, the transverse sediment and discharge dispatching should be strengthened in addition to making full use of existing facility for silt discharging. The dispatching principle is that in the flood season when sediment come from upstream is great, open the sluice gate and desilting facility of the Dajiang Channel ,the flood discharging gate more frequently to releases flow and flush silt.

3.2The dispatching scheme

Through the research we realized that after sediment-discharging gate of Da Jiang is opened, on the one hand deposition in channel may be effectively reduced, on the other hand streamline tend to move to the power plant in Da Jiang. This would result in increase in the sediment concentration in the power plant of Da Jiang, bringing disadvantageous influence to the power plant. Therefore, it appears especially important to put forward a moderate reservoir dispatching scheme that takes both factors into consideration.

A appropriate and applicable reservoir dispatching scheme should be based on the operation characteristic of Gezhouba Project, as well as the circumstance, the social and economic benefit of the project. Restricted to the present condition, this article emphatically studies how to reduce deposition and how to reduce the quantity of coarse sand passing through power plant in Da Jiang Project, and researches the feasibility of appropriate dispatching scheme from the point of the sediment movement in dam area.

Taking the present management and dispatching scheme as reference, four different reservoir dispatching schemes is studied by using discharge as: Q=20000m^3/s, Q=28400m^3/s, Q=40000m^3/s and Q=50000m^3/s respectively. The method is focused on the study of the variation of the sand concentration of the Dajiang power plant due to the opening and closing of the Dajiang sluice gates. When the sediment-discharging gate of the Dajiang is

closed, the main concern is about are how can the current from floodgates of Er Jiang in three different regions affect sediment concentration in power plant; when it is opened, the main concern is about the different flow-rates affected by the sediment concentration of the power plant.

3.3 Results predicted by different reservoir dispatching schemes

The calculated traverse sediment concentration curves at different discharge (q=28400m^3/s and 40000m3/s) are shown in figure 2 and 3. The specific scheme is shown in sheet 1、sheet 2.

Sheet1 q=28400m^3/s flow of the different main structure Unit（m3/s）

		Sluicing Gate of the Dajiang	Dajiang power plant	Bottom outlet of the sand sluicing	Flood Discharging Gate of the Erjiang			Erjiang Powe Plant
					Right zone	Middle zone	Left Zone	
Scheme1		12600	8603	604	1296	0	0	5297
2	(1)	0	8603	604	13896	0	0	5297
	(2)	0	8603	604	0	13896	0	5297
	(3)	0	8603	604	0	3896	10000	5297
3		0	13000	604	6796	0	0	5297
4		6600	8603	604	7296	0	0	5297

Sheet2 q=40000m3/s Flow of the different main structure Unit (m3/s)

		Sluicing Gate of the Dajiang	Dajiang power plant	Bottom outlet of the sand sluicing	Flood Discharging Gate of the Erjiang			Erjiang Powe Plant
					Right Zzone	Middle	Left Zone	
Scheme1		15390	12169	732	0	0	3520	8182
2	(1)	0	12169	732	0	14000	4917	8182
	(2)	0	12169	732	4917	14000	0	8182
	(3)	0	12169	732	14000	4917	0	8182
3		20000	11086	732	0	0	0	8182
4		8397	12169	732	0	7000	3520	8182

The analysis about the sediment dispatching are as follows:

(1) When sediment-discharging gate of Da Jiang and floodgates of Er Jiang are opened, the power plants of Da Jiang and Er Jiang may be affected greatly, but the influence might be varied based on the different operation condition.

(2) When the discharge is the same, it hardly has little influence on sediment concentration of the Da Jiang plant under the condition that all flow passes through the floodgate of Er Jiang, no matter which area(left ,right and the middle) the flow going by. The results also shows that sediment concentration of Da Jiang plant is a little big higher if the flow passing through the floodgate in the right area of Er Jiang; and if the flow passing through the left area, the sediment concentration of the Er Jiang plant would become higher, but the difference is not obvious.

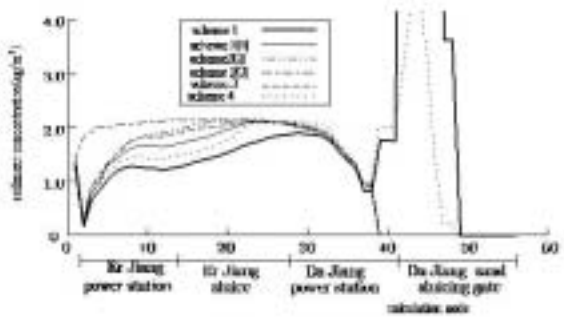

Fig 2 The calculated traverse sediment Concentration curves (q=28400m^3/s)

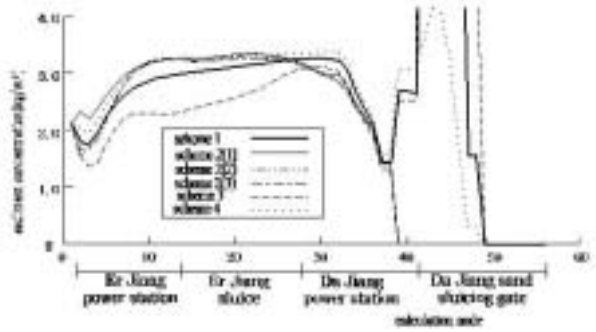

Fig 3 The calculated traverse sediment Concentration curves (q=40000m^3/s)

(3) When discharge keeps the same, how to dispatch the floodgate in the three different areas of Er Jiang has great influence on sediment concentration of both the Da Jiang and Er Jiang plants. Under the condition that the flow passing through sediment-discharging gate of Da Jiang, mean sediment concentration in vertical is not evenly distributed along the horizontal direction of the river, Moreover no matter how to dispatch the floodgates in the three areas of Er Jiang, sediment concentration in power plant of Da Jiang is larger than that of Er Jiang when flow passes through the sediment-discharging gate of Da Jiang,.Therefore it is showed that , Instead of Er Jiang ,the emphases of sediment preventing is Da Jiang plant . The Computation results indicated that sediment concentration may varied according to the different dispatching mode of the sluice gates of the Da Jiang and flood discharging gate of the Er Jiang . The sediment concentration of the Da Jiang plant is much higher than that of the Er Jiang when the entire flood discharging gates of the Er Jiang plants is closed. The sediment concentration along the transverse direction of the river is relatively symmetrical when the left part of the flood discharging gates of the Er Jiang is operated. While when the right part is opened, it will become uneven. If the flow is even distributed it indicates that it is of equal importance to prevent sediment for both of the Da Jiang and Er Jiang plants, otherwise it may be treated differently.

（4） The sediment concentration of the Da Jiang plant may be varied from the flow passing through the sediment sluicing gates.

It is indicated by the calculation that with the increase of the flow passing through sediment sluicing gates, the sediment concentration of the Da Jiang plant will be decreased. For scheme 1 and 4, with the flow equals 28400m3/s, 44.4% and 23.6% of the flow will pass

through the sediment sluicing gates respectively. For scheme 3, 1 and 4, with the flow equals 40000m3/s, 38.6% and 21% of the flow pass through the sediment sluicing gates respectively, the sediment concentration of the Da Jiang plant may be increased accordingly..

（5）With the joint dispatching of the Da Jiang and Er Jiang plants, in addition to discharging flow reasonably, it will be effective to decrease the sediment concentration of the Da Jiang plant. Shown by the calculation results, ①.when the discharging flow through the Da Jiang sluicing gates is relatively larger（For scheme 1 and 4,q=40000m^3/s）;, The sediment concentration of the Da Jiang plant will be increased under the condition that the either the flood discharging gates of the Er Jiang plant is closed or the flood discharging gates of the left part of the Er Jiang plant is opened.② .when the discharging flow through the Da Jiang sluicing gates is relatively smaller；Even if the the flood discharging gates of the Er Jiang plant is opened, The sediment concentration of the Da Jiang plant is still remains high level.（For scheme 1 and3,q=40000m^3/s）. ③. when the discharging flow through the Da Jiang sluicing gates is relatively smaller；the flood discharging gates of the left part of the Er Jiang plant is opened., sediment concentration will be increased even more higher（For scheme 4,q=40000m^3/s）.④The discharging flow through the sediment-discharging gate of Da Jiang plant accounts for 35%～50% of the total flow, in addition to the flow passing through the flood discharging gates of the ErJiang plant(accounts for 5%～10% of the total flow),it will be quite effective to decrease the sediment entering into the Da Jiang plant.

The above-mentioned study is aimed to decrease the sediment of the Da Jiang plant. As to the issue about the erosion and evolvement of the downstream channel caused by sediment suspending due to variation of the flow passing through the sand discharging gates of the Da Jiang plant, it is suggested that further research be carried out.

4 CONCLUTION AND SUGGESTION

This paper does a primary research on transverse sediment dispatching aimed at reducing sediment concentration in power plant and deposition in Da Jiang channel of Gezhou Dam. It is indicated that it would effectively reduce the quantity of coarse sand going through turbines and sediment concentration in power plant under the condition that the sediment-discharging gate of Da Jiang and flood discharging gate of Er Jiang is appropriately operated. We suggest that more research should be carried out by taking the factors as the index of electricity capacity, requirement of the navigation channel and social ecological environment into consideration. The final findings may be extended and applied in the Three Gorges Project based on the further study recommended.