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Analysis on Current Situation and Development Trend of Ecological Revetment Works in Middle and Lower Reaches of Yangtze River

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Abstract

In this article, analysis has been made with regard to current situation of ecological revetment works and revetment requirements of river channels in the middle and lower reaches of Yangtze River, types of ecological revetment and etc. The development trend of ecological revetment and its application prospect are also discussed. The analysis indicates that, after the impoundment of Three Gorge Reservoir, the erosion of the river channels in the middle and lower reaches of Yangtze River will result in severe situation like local river channel adjustment and local bank collapse and continuous weakening of river ecological system. It is necessary to keep on strengthening the comprehensive control of the river reaches adopting in the future.

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Keywords: Ecological revetment; toe protection; slope protection; Middle and Lower Reaches of Yangtze River; development trend

1. Introduction

The traditional revetment works strive for safety and cost-effectiveness in terms of structural type and material selection, laying particular stress on flood control functions and ignoring the ecological effect and landscaping demands, and some revetment types even have done certain harms to the ecology and environment of rivers. With the development of national economy and social advancement, to meet people's environmental demands, it is very urgent to carry out a new type of research on the revetment works integrated with flood control effect, ecological effect and landscape effect, which is a key issue to

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be solved at the moment as well as a development trend for the river control in modern times. Ma Ling et al. [1] indicate that the ecological revetment is a type of bank protection intended for protecting the river channel slope surface using the plants or the combination of the plants of civil works. With the social and economical development and the increase of people's awareness in ecological and environmental protection, Xu Fang et al. [2] indicate that ecological revetment will become the development trend for the river channel revetment works in the future.

The development of ecological revetment technique has experienced a process from illegibility to legibility and from singleness to diversification. The overseas research on ecological revetment technique was started very early. As early as in 1950s, "Near Nature River Channel Control Project" was proposed for the control works of Rhine River, considering that the river channels shall be controlled in accordance with the vegetalization and life-oriented principle. Dell Miller [3] indicates that USA and some countries of Europe have carried out great deal of research with regard to the revetment technique for "Soil Biological Works" and have created a set of complete theory systems and construction methods. Japan proposed a technique of "River Channel Control of Multi-nature type" at the beginning of 1990s and implemented the plan of creating rivers of multi-nature type; LARCZYK P, KRYSZTIAN W [4] discovered that Canada uses the straw reed for biological slope protection and has achieved good results. In recent years, with the social and economic development and the increase of people's environmental awareness and their demand for high quality environment, it is quite urgent to use new engineering structure types and new construction techniques for the revetment works of Yangtze River to improve their effect and overall technical level. At moment, The middle and lower reaches of Yangtze River are showing a trend of diversification in terms of revetment materials and engineering types and most of the researchers carried out related research in relation to the revetment works for the rivers or reservoirs or lakes of medium and small size. At present, comparatively, the application of biological revetment technique in the river channels in the middle and lower reaches of Yangtze River is seldom. In recent years, some relevant units at home have started their exploratory practice and some improved revetment types have been applied for some reaches in the middle and lower reaches of Yangtze River. For example, wire-mesh stone template was constructed for Nan wuzhou of Jingjiang River, geogrid stone template was constructed for the reach of Hongshui Harbor, and mesh-wire mold cobble drainage lower revetment technique was successfully applied for River Regime Control Project for Lower Jingjiang River Reach of Yangtze River (Hubei Section), which was completed in April, 2011. In the Phase II Control Project for Nanjing Reach of Yangtze River commenced in 2003, ecological revetment technique was applied for Meizizhou and Baguazhou Revetment works, greening and beautifying the environment of the bank and shoals, making the revetment works compatible with the ecology of the river channels. Moreover, the ecological bank protection types combined with plant measures and non-plant measures have also be arranged for the three uncompleted works of the important embankment concealment project of Yangtze River, for example, the test of the combination of foreign plant vetiveria zizanioides, local plant cynodon danodon dactylon and non-plant measure ecological concrete slope protection was conducted for lower reach of Jingjiang River. In addition, in recent years, Changjiang Waterway Design and Research Institute has used Reynold mat as the bank protection type in succession for Majiazui navigation channel in Shashi, Fuxingzhou section, Wen cunjia section and Xiangjiazhou section in Yanziwo navigation channel area in Jiayu and the reach of Huangshi in the middle reach of Yangtze River as well as the reach of Tongling in the lower reaches of Yangtze River, which favors the growth of plants and the maintaining of ecology. However, currently such research is still in a scattered and unsystematic state and can hardly play a guiding role in utilizing the bank and constructing embankment in the future and deeper research is to be done.

After Three Gorge Reservoir is put into operation, the river channels in the lower reaches of Yangtze River will undergo long-time and long-distance riverbed armoring process. In particular, with the

completion and operation of the cascade reservoirs groups such as Xiluodu and Xiangjiaba reservoirs in Jinshajiang River in the upper reaches of Yangtze River, the dispatching role of the reservoirs will bring certain changes to the condition of the water and sediment coming from the upper reaches. For example, the sudden rising up and down of the water level downstream the dam will have certain impact upon the stability of the soil body or the protection works on both banks. So it is necessary to keep on implementing the bank protection or reinforcement works. The ecological revetment conforms to the river control concept of “Building a healthy Yangtze River and Promoting Human-River Compatibility”, and the research on how to develop the new type of revetment techniques which can not only stabilize the river regime, ensure the flood control safety, maintain the ecological health, but also fully plays the role of landscape function has become the direction of river control.

2. Revetment Demand of River Channels in the Middle and Lower Reaches of Yangtze River

2.1. Short-term evolvement characteristics of river channels in the middle and lower reaches of Yangtze River

(1) Riverbed variation of erosion and deposition

Since Three Gorges Reservoir was put into operation, long-distance erosion has occurred to the river channels in the middle and lower reaches of Yangtze River from its upstream to downstream. According to reference [5], from Oct. 2002 to Oct.2010, Yichang-Hukou reach generally showed a feature that both river channel and beach are subject to erosion, and the erosion mainly occurred in the low-flow river channels, with a total erosion of 814million m³ and an annual erosion of 122 million m³, and an annual average erosion strength of 128200 m³/km.a. Judging from different reaches, the low-flow river channel erosion mainly occurred on Yichang-Chenglingji reach and the erosion in the reaches downstream chenglingji is minor. With the erosion going on, the erosion parts will develop continuously toward the lower reaches.

(2) Riverbed evolution characteristics

According to reference [5], Depending on river types, the river channels in the middle and lower reaches of Yangtze River is classified as straight reach, curve reach and branch reach. It is generally recognized that the upper Jingjiang River is a curve reach, the lower Jingjiang River is a winding reach and the reaches downstream Chenglingji are branch reaches. After the impoundment of Three Gorges Reservoir, the long reaches downstream the dam was subject to long-distance erosion, with no great variation in overall river regime, but with local adjustment. After Three Gorges Reservoirs was put into operation, Yichang-Chenglingji reach shows little variation in river channel plane configuration. With a strong control capability, the boundaries on both banks of the gravel reach have a stable plane configuration and mainly demonstrate channel erosion and riverbed armoring after the impoundment. According to reference [6], from the upstream to downstream, Jingjiang River has 15 curves, in which the curves Haoxue, Tiaoguan, Jingyugou, Fanzui, Qigongling, Guanyin Zhou and etc are characterized by stable curve riverbed and long silted convex bank, and the rest are the curve and branch reaches characterized by division and combination of shoals in the river and the variation of the right and left branches. As the concave banks in the curve reaches are protected by the revetment works, the plane configuration and deep channels mostly remain stable after the impoundment of Three Gorges Reservoir. Although the low and high beaches on the convex banks have expanded or subsided due to siltation to different extent, the side beaches on the convex bank of the curve channel are still comparatively stable as a whole, to which no large-sized beach cutting has occurred; Due to the revetment works (or natural node) for the concave bank in the curve and branch beach, the reaches of such types are mostly stable in plane configuration and Thalweg after the impoundment of Three Gorges Reservoir. However, with the

impoundment development of Three Gorges Reservoir, the bank collapse phenomenon due to the local river regime adjustment due to evolution will become more severe, to which attention shall be attached.

2.2. Analysis on revetment demand during the continuous erosion of riverbed

(1) Riverbank stability during the continuous erosion

Except the low hills close to the river in the partial reaches, most of the riverbanks on the boundary of the mainstream riverbed in the middle and lower reaches of Yangtze River are composed of 25-100m thick loose sediment, which are layered and of binary structure. The upper layer is the clay of river floodplain, with a thickness of 4-30m. The lower layer is the medium fine sand of river bed phase with a thickness of several meters to about 60m. Yue Hongyan et al [7]. Indicate that due to the difference of clay and sand in physical and chemical property, stress characteristic and movement under the action of water current are quite different, showing obvious difference in anti-erosion. At the depth of 10m, the starting speed of the fine sand is approximately 0.7m/s, while the clay is approximately 2.7m/s. At the water depth of 20m, the starting speed of the fine sand is about 0.8m/s, while the clay is about 4.2m/s. The difference between them is greater at deeper water depth. Under natural circumstances, the water depth alongshore in flood season in the middle and lower reaches of Yangtze River is more than 20m and the maximum vertical line average velocity of flow alongshore is generally more than 3m/s and up to 4m/s. The measured data also shows that the velocity of flow alongshore at the middle river level is up to 1.29-1.59m/s. This indicates that the upper clay of the bank slope of binary structure in the middle and lower reaches of Yangtze River is firm enough to resist the scouring or is basically not scoured under the action of water current, while the lower fine sand can be easily started. When the lower fine sand is subject to erosion, the slope of the sand layer becomes steeper, as a result of which the bank collapse can easily occur.

Under the specific geological condition of the binary structure of the river channels in the middle and lower reaches of Yangtze River, the discharge of clean water from Three Gorges will result in the long-distance erosion. According to the measured information, the current characteristic of the erosion and siltation is that the erosion of the low-flow channel is most serious, which will further deteriorate the slope foundation erosion of the riverbank or beaches of binary structure, leading to steeper bank slope and adverse effect upon the safety of the embankment and accelerating the bank collapse at existing locations or give rise to new bank collapse. The information measured during 2003-2007 after the impoundment of Three Gorges Reservoirs indicate, 101 major bank collapses occurred to the mainstream of Jinjiang River, with an annual times of collapse of about 34 and an annual average collapsed length of 33.64km. Compared with the situation before the impoundment, the frequency of the occurrence of bank collapse is obviously increased. The bank collapse not only occurred to the sections free of revetment, but also to the sections with revetment. For example, major bank collapse occurred to Xiangjiazhou bank revetment section of river channel in Shishou, Tuanjiezha bank revetment section of the reach of Jianli. The measured information on bank collapse of lower reaches after the application of other reservoirs at home and abroad also indicates the existence of the above-mentioned phenomenon. For example, the annual bank collapse rate of the river channels in the lower reaches was increased by about 1/3 after Danjiangkou Reservoir was put into operation. Therefore, the top priority for the revetment is to ensure the embankment stability and safeguard the flood control safety during the continuous erosion of the river channels in the middle and lower reaches of Yangtze River after the impoundment of Three Gorges Reservoir. To achieve it, it is required to attach more importance to the protection of bottom sand layer in the binary structure.

(2) Maintaining of perfect river channel ecology

Judging from the horizontal direction of the river channel, the river ecosystem is classified as aquatic

and riverbank sub-ecosystems. The riverbank ecosystem is an important component part of the river ecosystem and the continuity is one of the important characteristics of river ecosystem. When the traditional revetment works such as concrete and masonry slope protection which artificially solidify the riverbank are employed, the aquatic ecosystem and the riverbank ecosystem are separated, inevitably doing harm to the biology diversity, ecological balance and environmental protection. Upon the completion of Three Gorge Reservoir, the variation of flow and sedimentation process plus the erosion of riverbed will further reduce the lateral continuity, destroy the heterogeneity of habitat and slow down its natural succession rate, thus bringing adverse effect upon the biological diversity.

In recent years, the environmental issues of rivers attributable to the development and utilization of water resources are gradually drawing people's attention. People have realized that, to achieve the sustainable development of rivers, protection and development shall be carried out at the same time. With the initiation of some important concepts like "Human-nature harmony" and "Human-water harmony", it has become a new way of thinking to maintain the healthy of rivers. With the rapid development of social economy and the growing of awareness in ecological and environmental protection in our country, the revetment works are required to provide people with a nice water environment, resume the vital force of nature and facilitate the biological diversity and improvement of water quality of rivers.

(3) Selection of revetment time

Due to the local river regime adjustment as a result of variation of flow and sedimentation condition and the riverbed erosion, the selection of the execution time of revetment works after the impoundment of Three Gorges Reservoir shall be subject to the river regime control planning of reaches. The right execution time is when the bank line reaches the planning and control guiding line. The execution at a too early or late time will make the river regime not smooth and the revetment works itself not stable.

3. Types of Ecological Revetment for River Channels in the Middle and Lower Reaches of Yangtze River and their Application Prospect

3.1. Types of Ecological revetment for river channels in the middle and lower reaches of Yangtze River

The revetment works in the middle and lower reaches of Yangtze River is generally classified as aquatic slope protection and underwater toe protection, with the low water level as their boundary. After the impoundment of Three Gorges Reservoir, the middle and lower reaches of Yangtze River will be subjected to continuous erosion to a certain extent. From the point view of safeguarding the embankment safety, stabilizing and maintaining the continuity of river channel ecological system, preliminary analysis focusing on the type, material, advantages and disadvantages of the slope protection and toe protection is made as follows:

3.1.1. Aquatic ecological slope protection

In constructing the flood control works in the middle and lower reaches of Yangtze River, the common slope protection works above the low water level mainly includes the structural types such as dry masonry, grouted masonry, bag concrete, and concrete precast blocks. However, the slope protections of above-mentioned types do not have ecological and landscape functions. Firstly, the materials used can not play a role of environmental protection. For example, the dry masonry is produced by blasting the mountains and the destroyed vegetation can hardly be repaired, while the bag concrete is made of the cement consuming high industrial energy and bringing about waste gas emission, which is obviously not the slope protection material of environmental-friendly type. Secondly, the whole slope protection artificially obstructs the connection between the riverbank ecosystem and aquatic ecosystem, bringing adverse effect upon the biological diversity; thirdly, the whole slope protection area belongs to the river

channel of artificial type, which is poor in landscape function and can hardly be compatible with the surrounding environment.

To meet the need of the ecological function of the aquatic slope protection, rebuild the river channel of “natural type” and achieve the harmonious co-existence of human and nature, the revetment works in our country are beginning to develop toward the ecological type, with allowance made for ecology maintaining, environmental beautification and water quality improvement, having creating the ecological slope protection of various kinds.

3.1.2. Underwater toe protection

Traditionally, the toe protection types such as ripraps, bag concrete, framework with four permeable sides, reinforced gabion, sand pillow bag, hinged concrete mattress are used below the low water level. Among them, the ripraps are most common type in the middle and lower reaches of Yangtze River. The riprap is fast in construction, providing quick result and durability, and can be adjusted automatically with the deformation of riverbed.

Importance shall be specially attached to the toe protection works during the continuous erosion after the impoundment of Three Gorges Reservoir. It is recommended to use the materials with strong anti-erosion ability and strong adaptability to riverbed deformation, such as riprap, reinforced gabion. The underwater ecological cobble cage or mesh membrane cobble mattress newly designed by Changjiang Scientific Research Institute has a perfect application effect. On one hand, better flexibility and permeability of stone cage structure are achieved, which is adaptable to the riverbed deformation of riverbed. The multi-hole construction of the cage is not only a good place for biological inhabitation, but also suitable for the vegetable growth. Moreover, as the cobbles mostly come from the natural rivers and lakes, the environment pollution caused by the mining of stones can be avoided.

3.2. Application prospect

Ecological revetment is the development trend and new requirement for revetment construction in the current stage and in the future, indicating that the water conservancy works construction in our country has been developed to an important historical stage of “allowing the river channels to return to nature”. In the current situation where nature is greatly stressed and ecological river channels are rebuilt, human-nature compatibility shall be achieved for more and more river channel revetment works, so that the basic need of flood control and discharge can be met and the river channel revetment work can be carried out from the ecological and sustainable development point of view. If the following several issues can be settled in the research work in the future, the ecological revetment application will have a wide prospect.

(1) Strengthen the research on the ecological revetment mechanism of different types. The existing ecological revetment researches mostly focus on the selection and matching of vegetation, selection of revetment materials, optimization of structure types, while the research on revetment mechanism is rare.

(2) Strengthen the research on ecological effect of the ecological revetment. Located at the water -land boundary where the active substances, energy and information are flowing, the revetment is more distinct than other adjacent systems in biodiversity characteristics. Hence, the research on its ecological effect shall be strengthened from the points of views such as substance flowing, energy flowing and food chain relation in the future.

(3) Strengthen the research on the design and construction code of the ecological revetment of different structure and types. The ecological revetment is diversified in terms of materials and structure type and is subject to the location and weather condition. While a uniform design and construction code for the ecological revetment isn't available. Theoretical research lags behind the need of engineering application.

4. Conclusion

After Three Gorge Reservoir is put into operation, the erosion of the river channels in the middle and lower reaches of Yangtze River will tend to become more serious in both extent and scope than before. In this article, analysis has been made with regard to current situation of ecological revetment works and revetment requirements of river channels in the middle and lower reaches of Yangtze River, types of ecological revetment and etc, and the development trend of ecological revetment and its application prospect are also discussed. The analysis indicates that, after the impoundment of Three Gorge Reservoir, the river channels in the middle and lower reaches of Yangtze River will be caused persistent erosion for a long period of time and a long distance, resulting in severe situation like local river channel adjustment and local bank collapse and continuous weakening of river ecological system, and it is necessary to keep on strengthening the comprehensive control of the river reaches with bank collapse and dangerous sections in the future, and re-understand the control of the existing river channels in terms of planning, design, construction, maintenance, management and materials to expand the ecological control of the river from a given river and reach to its region and drainage basin. It is also necessary to strengthen the research on protection mechanism, ecological effect and design code for the ecological revetment of different types. With more and more importance attached to the ecological and environmental protection by the people, it is estimated that the application prospect of ecological revetment of the river channels in the middle and lower reaches of Yangtze River will be very wide in the future.

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