Research on Biological Protection Engineering Construction on Downstream Levee of the Yellow River

Yuan Zhanjun¹,a, Zhang Feng²,b

¹Water Supply Bureau, YRCC, Zhengzhou, Henan, 450003, China
²Hydrology Bureau, Yrcc, YRCC, Zhengzhou, Henan, 450008, China
¹yuanzj2004@126.com, b76795069@qq.com

Abstract: As an integral part of flood control engineering system, biological protection measures have always been attached great importance to by management units at all levels. Taking the calculation of the width of the breaktide belt in the lower reaches of the Yellow River as an example, this paper studies the great role of the protection works in ensuring the safety of the Yellow River project protection and the construction of water ecological civilization.

1. Introduction
The biological protection engineering mainly includes development of riverside wave break forests, crest passage forests, suitable forests in the silt area, protection forests against river, levee slope turf protection and courtyard afforestation, etc. Through the multi-year construction, the biological protection engineering construction of the Yellow River has been vigorously carried out according to the principles of riverside wave break, local material collection and utilization, arbor and shrub combination and planting according to the environment, and a standard levee system marked by “flood control security line, traffic line for emergency rescue and eco-landscape line”, has been built.

2. History of Tree Plantation on Levee
The tree plantation on the levee of the Yellow River has had a long history. The concept of biological protection was not explicitly mentioned in the history, but the biological protective measures were once clearly expressed. For instance, there was a literal stipulation over “the willows and elms along the river”, aiming to consolidate the levee in the Song Dynasty. In the Ming Dynasty, Liu Tianhe summarized his experience in planting trees on the levee, namely the six willow planting methods — “deep planting, willow burying, weaving, willow planting in deep pit, sheetflood-resisting willow and planting of tall and thick willows”, and comprehensively generalized the protection forest planting on levee. In the Qing Dynasty, “planting willows 100 feet inside and outside the levee” was explicitly stipulated, the willows were cultivated on official land to form forests, which could not only protect the levee but also provide local materials for the levee construction.

After the Yellow River returned to the original river course in 1947, the people in the liberated areas carried out the tree planting activities along the two river banks under the leadership of governments at all levels.

Since the founding of the People’s Republic of China in 1949, the competent authorities in charge of the Yellow River channel have summarized the historical experience, put forward the tree planting principles of “riverside wave break and local material collection and utilization”, and listed the tree planting and levee greening as the guidelines into the annual engineering management plan. The tree
planting and greening activities are carried out in spring and winter ever year.

In 1976, Yellow River Conservancy Commission printed and distributed Opinions about Afforestation on the Yellow River Levee, “zoyia metrella instead of trees should be planted on the levee in order to facilitate the flood prevention and emergency rescue, and to prevent trees from falling during the flood and avoid root rotting, which may generate various hidden dangers. The original arbors and shrubs on the levee slope back to the Yellow River should be gradually eliminated by combining the levee repair. Clumping willows can be planted in the shade of willow trees along the river to slow down the water flow and protect the levee, thus forming a three-level wave break forest that is high inside and low outside. Fast-growing commercial forests should be the emphasis in the shade of willow trees against river. Passage forests can be planted on the shoulder of levee, including shallow aspens, chinaberies, paulownias, etc. with few roots”.

3. Hazards and Reform of Tree Planting on Levee

The tree planting on the levee of the Yellow River has a long history, where the main tree species is willow, together with Yuanliu (or citron willow), elm, aspen, tung tree, cypress, etc. However, the tree planting on the levee of the Yellow River has always been controversial, among which an opinion is that: The tree planting on the levee body is one of the flood control bioengineering measures, playing a significant role in wind prevention and sand fixation, scour prevention and dyke strengthening, water flow retarding and silt accommodation, maintaining the engineering integrity, providing rescue materials, improving and regulating the regional climate, and guaranteeing the flood control safety of the Yellow River. Meanwhile, certain economic benefits can be achieved by planting the trees on the levee, which will be beneficial for stabilizing the dam reinforcing team. Another opinion is: The tree planting on the levee is featured by large investment and poor economic performance, and it affects the project inspection and emergency rescue work. Under stormy weather, the trees will shake, thus aggravating the seepage failure of levee body, especially the rotted roots will weaken the strength of the levee body.

In order to scientifically evaluate the floor control effect and economic benefits generated by planting trees on the levee body, the tree growth laws and hazards must be analytically investigated. In 1986, Yellow River Conservancy Commission dissected willows, Yuanliu and elms planted on the levee of the Yellow River, it appeared that the tree age ranged from 17 to 31 years, and the tree roots had the following features:

- In order to absorb the moisture, tree roots developed towards the direction of high moisture content. For instance, in 1931, the roots of willow trees on the levee of the Yellow River were deeply rooted beneath the riverside dangerous section and even beneath the low water level. The softer the soil texture, the thicker and longer the tree roots. The tree roots presented exuberant growth and development in sandy soil. At the soil layer with silty blocks or hard soil layer, the tree roots were shrunk or branched with changed direction, and then grew towards inside the soft soil.

- Is it suitable to plant trees on the levee? Can trees be planted on the levee? The economic benefits should be considered, and more importantly, the influence of tree planting on the levee on the flood control safety should be analyzed. Therefore, Yellow River Conservancy Commission paid a high attention, and through the multi-year repeated excavation and analytical demonstration together with the relevant bureaus in Henan and Shandong, the basic conclusions were as follows: The tree root should be as deep as the tree. Some trees were planted at the riverside, and roots penetrated through the riverside. Therefore, planting trees on the levee exerted a destructive effect, and would go against the flood inspection and control.

- By asking for opinions from multiple parties and repeated studies in 1987, Yellow River Conservancy Commission decided not to plant trees on the levee any longer, and gradually eliminated the existing trees. The levee slope and shoulder were turfed. According to Article V in Assessment Standard for Yellow River Downstream Engineering Management enacted in 1987, levee greening, except that a row of passage forest was reserved at each side of levee shoulder beside the Yellow River, no trees should be planted at the riverside or on the back slope. The grass planting was conducted on the levee shoulder and slope, and the turf coverage was not lower than 98%. Three-level (low, medium and high) willow
forest was planted in the shade of willow trees beside the river to resist waves. Willows or other arbors were planted in the shade of willow trees against river. In the silt area, a forest would be formed or other tree species might be developed.

Through the gradual construction and development since 1990, the relatively complete biological protection engineering system with unique characteristics of the Yellow River has been preliminarily formed.

4. Results of Biological Protection Engineering Construction

In accordance with Design Specification for Levee Project Management (SL171-96), the Yellow River biological protection project aims to attenuate waves and prevent storm flood, sand wind, sleet and waves from scouring, eroding and destructing the levee project, protect the footing safety of levee and revetment project, construct a commercial forest base for the flood control, conserve the land and soil, afforest the levee and optimize the ecological environment.

The Yellow River belongs to a northern river that is dry with less rainfall, the flood mostly occurs in the three periods of hot season, and autumn. In order to ensure the flood control safety and afforest the levee conditionally, based on multi-year practice, Yellow River Conservancy Commission took full consideration of environmental protection, water and soil conservation and plant growth, adhered to the principles of making overall plans, reasonable planning and uniform layout, and clarified the planting principles and technical standards of riverside wave break forest, passage forest on levee shoulder, suitable forest in the silt area, and protection forest against river[1].

4.1. Riverside wave break forest

After the flood of the Yellow River overflows beach land, the levee impact and scouring generated by the stormy waves will be rather serious, especially in the section where the floodwater will be drawn off, the safety of levee will be seriously threatened, so construction of protective dam and riverside willow planting, etc. are traditionally taken as the measures to realize the wave resistance and scour prevention, and these matures can exert a very good effect without any doubt. However, the construction of flood dam is of large investment, large engineering quantities, large maintenance workload and increasing input. The temporary willow planting is relatively passive, failing to effectively solve the wave resistance problem. Therefore, construct the wave break forest-centered biological wave protection works is a significant measure ensuring the flood control safety of the Yellow River, along with major flood control benefits, economic benefits and ecological benefits.

The wave break forest should be cultivated within a certain scope at the riverside of the levee project according to unified specifications and technical requirements. Arbors, shrubs and herbaceous plants should be combined to form a tight three-dimensional biological wave prevention project. The nursery-grown plants in the wave break forest should be Salicaceae with good flooding resistance, flexible texture, crown development and high growth rate or other tree species suitable to grow locally. The planting width, number of rows and plant spacing of the wave break forest should be determined according to the wave attenuation and scour prevention requirements while not affecting the safe flood discharge. When necessary, it should be determined through a comparative analysis using the observation and test results of wave break forests under the similar conditions[2][3].

The main factors of wave elimination are the height of the outer edge of the forest, the width of the forest, the planting density and the mean diameter of the trunk at the water surface. According to the wave-suppression coefficient and wave-break width formulas provided by Hubei Provincial Department of Water Resources, they are as follows[4][5]:

\[ K = \left( K_f H_0 - H_{1/10} \right) / K_f H_0 \]

where:
- \( K \) — Wave attenuation coefficient;
- \( K_f \) — coefficient, \( K_f = 0.96 \);
- \( H_0 \) — Wave height at the outer edge of the forest, \( H_0 = 18v_{10}^{62}F^{1/3}, v_{10} \) is the wind speed at 10m above the water surface, generally \( v_{10} = 15 \); \( F \) is the effective blowing distance (km), 10km and 6km are taken above Gaocun section of the Yellow River, and 3km are taken below Gaocun section of
the Yellow River.

\[ H_{1/10} \text{—— waves high at the bank slope. the actual situation of the Yellow River is generally 30 cm} \]

The formula provided by Hubei Provincial Department of Water Resources on the test and research results of breakwater forest is still used to calculate the width of breakwater forest:

\[
K = \frac{1}{1 + 1.30^{0.0167H_0 - 2.53\log B - 1.92\log D - 1.45\log \Phi}}
\]

- \( K \) — Wave attenuation coefficient;
- \( B \) — width of wave break forest; m
- \( D \) — planting density
- \( \Phi \) — Average diameter of tree trunk at water level; \( \Phi = 0.12 \) m

| Table 1 width value of breaktide forest in the lower Yellow River | unit (m) |
|---------------------|----------|
| Density | 1m×1m | 1.5m×1.5m | 2m×2m |
| blowing distance | 90% | 80% | 70% | 90% | 80% | 70% | 90% | 80% | 70% |
| 10km | 125 | 60 | 37 | 251 | 111 | 68 | 361 | 172 | 104 |
| 6km | 107 | 51 | 31 | 199 | 93 | 58 | 308 | 146 | 90 |
| 3km | 83 | 40 | 24 | 153 | 73 | 45 | 238 | 112 | 69 |

It can be seen from the calculation results in Table 1 that the larger the blowing distance, the smaller the planting density and the larger the width of the required breakwater forest. According to calculation, above the high village section of the Yellow River, the width of the breakwater forest needs to be above 68 meters, and below the high village section, the width of the breakwater forest needs to be above 45 meters. Restricted by the narrow beach area of the lower Yellow River, the YRCC clearly stipulated that the width of the breakwater forest above the high village section should be 50m, and that below the high village section should be 30m. Willow was the main preferred tree species, with the conventional willow and weeping willow.

4.2. Protection forest against river

Aspens and willows are mainly planted on the dike dam against the river, which can not only protect the dam but also provide local materials to reinforce the levee, and reach the goals of wind prevention and sand fixation and environmental greening. The levee protective forest belt should be cultivated within the scope of dike dam at the side against the river of the levee project. The tree species adaptive to the local soil and climatic conditions, good texture, fast growth, high economic benefit and emergency rescue materials should be selected. The planting width and density in the levee protective forest belt should be determined according to the local soil and climatic conditions and environmental requirements like sand wind prevention and water and soil conservancy, etc.

4.3. Suitable forest in the silt area

After the standard levee of the Yellow River is constructed, a silt area with width of 80-100 m has been formed. According to the comprehensive Yellow River flood control plan approved by the State Council, the suitable forest should be planted according to the local environmental and geological conditions, in order to conserve the water and soil and reduce the soil loss. Aspens are mostly planted in this area, and they can also be used to cultivate nursery-grown plants and economic forests.

4.4. Passage forest on levee shoulder

The passage forest mainly aims to beautify the levee shoulder and contribute to the river regulation works. On the roads connecting the levee and the levee shoulder, evergreen shrubs are generally selected, and in principle, tall arbor species are not the options.

No trees should be planted within the scope of levee slope and berm. For the levee works cultivated with trees, the necessary technical safety demonstration should be conducted to determine whether the trees should be reserved. No passage forest should be arranged on the levee crest. When this becomes
necessary through the demonstration, the shrub species with shallow roots should be chosen.

5. Conclusions
Under the guidance of Yellow River Conservancy Commission and supported by the governments at all levels along the river since the founding of the People’s Republic of China, trees and turfs have been planted year by year by following the unified levee planning on the two river banks, which not only create the Yellow River protection forest belt, improve the natural environment, afforest and effectively protect the levee, but also provide a large quantity of materials for the flood control project construction, flood prevention and emergency rescue, and moreover, this plays an irreplaceable role in ensuring the flood control project safety and water ecological civilization construction.

References
[1] Miao, C., Yang, M., Su, Y. (2003) Flood Control and Project Management in the Lower Yellow River. Yellow River Conservancy Press, Zhengzhou.
[2] Liu, D. (2012) Study on the influence of the width of biological breakwater forest on the effect of wave elimination. China Agricultural Information, 7:74-75.
[3] Ji, H., Huang, B., Qu, X. (2005) Review of researches on wave reduction in plants. Hydro-Science and Engineering, 3:75-78.
[4] Ti, Y., Liu J., Pan M. (2019) Discussion on width design method of levee breakwater forest. YELLOW RIVER, 9:51-58.
[5] Zhang, M., Song, Z. (2013) Calculation of wave elimination performance of breakwater forest with different phase structures. Advances in Science and Technology of Water Resources, 33:40-43.