Research on Urban Ecological Levees under the Background of the Great Protection of the Yangtze River

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Abstract. The proposal of the Yangtze River protection concept puts forward higher requirements for the ecological protection of cities along the Yangtze River. In recent years, the function of urban levees has gradually expanded from a single flood control function to ecological and social service function, playing an increasingly important role in improving the urban ecological environment and enhancing the image of city. This study proposes some new concepts of urban ecological levee planning and design, by combining the new development theory of the Yangtze River with the successful practical experience of urban ecological levee construction. Then, typical cross-sections of urban ecological levee have been introduced as well as a case study of the construction of urban ecological levee. At last, some challenges of the urban ecological levee construction have been analysed. The research can provide guidelines for the planning and design of urban ecological levees.

Keywords: Ecological levee; Water ecological protection; Urban Flood Control; Yangtze River.

1. Introduction
The spirit of Chinese President Xi Jinping's speech on promoting the economic development of the Yangtze River emphasized the policy of “to protect together and not to engage in large-scale development”, and pointed out a clear direction for solving the ecological and environmental problems that have emerged in the economic and social development of the Yangtze River Basin. In the new era, a high-quality development path with production development, affluent life and good ecology need to be explored for the Yangtze River Basin [1].

In the process of human development, most of the famous cities are built along the river or coastal. Levee, which is a widely used water-retaining structure and very important to city's flood prevention. In a certain period of time, due to the limitations of economic development and the level of understanding, the ecological protection of rivers and lakes has been neglected in the construction of urban levees in China [2], resulting in poor quality of urban levee shorelines, serious occupation of shorelines, and non-hydrophilic waterfront problems. The transformation of urban levees from traditional flood control projects to "flood control, landscape and ecology" trinity complex projects becomes to the trend of urban levee. The construction and research of ecological levees are more urgent, as the concept of great protection of the Yangtze River puts forward higher requirements for the ecological protection of cities along the Yangtze River.
The urban ecological levee has already been studied by many scholars in China. For example, Dong [3] analyzed the impact of embankment construction on the river ecosystem, and proposed that the construction of ecological water conservancy projects should maximize the heterogeneity of river morphology. Liu [4] believed that urban embankment construction cannot be completely separated from overall urban construction, and implied that the construction of urban levees should adopt the appropriate method of landscape design. Zhu et al. [5] analyzed the necessity and benefits of ecological levee construction, and gave examples of ecological levee construction. Zhang et al. [6] studied the adverse impact of levee construction on the bio-diversity, and gave suggestions for strengthening the construction of ecological levees. Zhao [7] analyzed the problems emerging in the development of ecological levees in Hubei Province, and put forward the basic ideas for accelerating the construction of ecological levees. Li et al. [8] summarized the research on the urban flood control projects, and suggested that the design of urban flood control projects should integrate with the waterfront space design.

This study proposes some new concepts of urban ecological levee planning and design, by combining the new development theory of the Yangtze River with the successful practical experience of urban ecological levee construction. Then, typical cross-sections of urban ecological levee have been introduced as well as a case study of the construction of urban ecological levee. At last, some challenges of the urban ecological levee construction have been analyzed.

2. New concept of urban ecological levee planning and design

The levees play a vital role in the flood prevention and security of the cities along the river, which usually are densely populated and economically developed areas. With the improvement of Chinese economic level, the people's requirements for urban landscape and ecological environment have also been raised. In the new stage of development, water, as an important element for the survival and development of cities, has become more prominent. The function of urban levees has gradually expanded from single flood control to ecological and social service, which plays an increasingly important role in improving the urban ecological environment and enhancing the urban landscape. Ecological levee is a kind of a water-retaining project that meets the requirements of flood control, protection and restoration of the water ecosystem and its ecological service functions. It is required that the ecological levee as a flood control project has the characteristics of landscape, hydrophilicity, and ecology at the same time. Therefore, the construction of urban ecological levees should strengthen the protection of ecological space on one hand, and expand the service functions of ecological space on the other hand. Since the concept of great protection of the Yangtze River was proposed, local governments along the Yangtze River have successively carried out special rectification actions on illegal docks along the river, illegal transfer, disposal of solid waste, ship pollution and so on. The production coastline has retreated significantly, and the environmental remediation efforts and capital investment along the river have been strengthened. In this context, the following aspects should be paid attention to during the planning and design of urban ecological levees:

(1) The construction of urban ecological levees should be combined with the protection and restoration of aquatic ecosystems.

The levee is the boundary between the water area and the land area, as well as an important part of the river and lake shoreline and an important habitat for aquatic organisms to survive. Due to the limitation of understanding, China has neglected the protection of the ecological environment in the process of urban development in the past, which is mainly reflected in the following aspects. Firstly, reclaiming land from lakes (landing) encroached the blue-green space. Secondly, the hardening and canalizing of some river have changed the natural attributes of the river, resulting in the invaded the biological habitat, separation of the water and land system [9], and damage of the river’s ecological background. Thirdly, during the process of developing of the urban industry and increasing of population, the protection of the water environment is neglected, which resulted in the urban river section becoming a fragile part of the river ecosystem and the water environment degradation.
Therefore, the protection and restoration of the water ecosystem should be emphasized in the construction of urban ecological levees. Three measures have been suggested as following:

Firstly, more attention should be focused on the renovation of the shoreline. Effective measures such as ecological transformation of the levees, shoreline retreat, and ecological restoration of shorelines should be taken to restore the rivers and lakes where the ecosystem has been severely damaged. Ecological buffers should also be established in the levees where construction conditions are satisfied.

Secondly, the topography of the river should be improved. When building and rebuilding levees, the meandering of the river should be maintained, beaches should be reserved reasonably, and various cross-sections should be created to maintain the diversity of rivers and lakes.

Thirdly, the non-point source pollution should be reduced. The construction of ecological levees can be combined with the construction of sponge cities to reduce non-point source pollution through taking some effective measures, such as permeable paving and sinking green spaces. In addition, the construction of wetlands and forest parks should be combined with creating a good habitat to promote the protection and restoration of the water ecosystem of the river.

(2) The construction of urban ecological levees should be combined with the construction of urban landscape and culture.

The waterfront space, which holds various urban ecological resources, should be the focus of the construction of an ecologically civilized city. It is also the most precious area for creating representative landscape of the riverside city. The planning and construction of ecological levees should be incorporated into the overall urban planning, as an important facility for the urban ecological service function, to realize the connection and natural integration of flood control and leisure functions. In the planning and design of urban ecological levees, on the one hand, important landscape such as wetland parks and country parks can be created on the tidal flat ground to build water-friendly and waterfront spaces that reflect the natural beauty of rivers and lakes; on the other hand, the landscape should be integrated with native urban culture, especially the flood control culture, to highlight the urbanized civilization. For example, the Hankou ecological levees, located in the central area of Wuhan city, show the origin of the Yangtze River and the wharf culture of Wuhan through the Yangtze River bio-fossil relief slope and the wharf cultural exhibition area, which makes Wuhan a more charming city.

(3) Urban ecological levee construction should be combined with urban infrastructure construction.

With the development and practice of urban space planning concepts, ecological levees, as a part of urban infrastructure construction, gradually play a more important role in urban development and construction. The construction of urban levees is also more frequently combined with municipal roads, parking lots, beach stadiums and other urban infrastructure to realize the comprehensive utilization of land space, provide space resources for ecological protection, and expand the radiation range of advantageous ecological resources. For example, the type of levee combined with roads can be used to relieve traffic pressure and save land and resources on one hand, and on the other hand, it is beneficial to improve the urban environment and enhance the quality of life in the city [10].

3. Types of urban ecological levees

In recent years, China has made some attempts in the construction of urban ecological levees, and explored some new types of ecological levees. There are three types of urban ecological levees, which have been widely applied in cities along the Yangtze river, namely large compound section levee, small slope ratio ecological levee, and building inside ecological levee.

(1) Large compound section ecological levee

The large compound section is a river section composed of more than two different shapes of water-passing sections (see Figure 1). There are one or more hydrophilic platforms on the levee section, and the width of the hydrophilic platform usually reaches 50 to 100 m. The large compound section ecological levee has two obvious advantages. Firstly, it can effectively solve the problem of insufficient hydrophilicity of urban levees under constant water level. Secondly, the platform is large
enough to provide convenient terrain conditions for landscape construction. The elevation of the hydrophilic platform can be determined by hydrological frequency to create a friendly environment for animals and plants. For medium and small rivers, the compound section is conducive to the reserved beach land to form an ecological buffer zone, which plays a better role in ecological protection and restoration.

(2) Small slope ratio ecological levee
The small slope ratio ecological levee refers to the type of the urban levee, whose slope ratio of the levee section is smaller than the traditional levee section, which is generally less than 1:5. Small slope ratio ecological levee can visually eliminate the barrier effect brought by the levee, and effectively connect the city, the levee, and the beach to form a continuous landscape space. As the slope ratio is relatively gentle, it is helpful to the arrangement of plants and the creation of various spatial morphological of the levees through the micro-topography, making the levees more natural and beautiful. In the planning and design of small slope ratio ecological levee, the cross-section of the ecological levee can be divided into flood control section and landscape section (see Figure 2), which are implemented step by step according to different construction standards, thereby saving project investment and shortening the construction period. In addition, the small slope ratio ecological levee, where a large quantity of soil is needed to fill the landscape section, is helpful for solving the problem of soil absorption in urban river improvement projection.

(3) Building inside ecological levee
The building inside levee refers to the arrangement of box buildings inside the mall slope ratio levee (see Figure 1). On one hand, the buildings can take on the role of flood control walls, as a part of the levee, to resist the flood. On the other hand, the internal space of the building can be used as infrastructure, such as management houses and underground parking, to make full use of the space. Therefore, the construction of building inside levee must meet both the requirements of water conservancy projects and the requirements of building design. Besides, as a public activity space, it has potential dangers to the safe operation of levees. So, it is a challenge for civil engineers to plan and design building inside levee. Therefore, in the planning stage, the scale and function of the building should be verified carefully. The anti-seepage treatment and fire issue should also be paid enough attention.

4. Case study
The environment and ecology improvement project of the exit section of the Fuhuan River, a tributary of the Yangtze River in Wuhan, is located in the starting area of the planned Yangtze River New Town in Wuhan. In 2006, the preliminary design report of the project was approved and the construction started in the same time. However, due to various reasons such as lack of the construction funds, only a small part of the project was implemented. In 2017, the 13th Party Congress of Wuhan approved the proposal of planning and construction of the Yangtze River New Town. The Fuhuan River exiting section was used as an important ecological corridor of the Yangtze River New Town. During the re-planning and design process, the traditional levee type was changed to the ecological levee type. The length of the new ecological levee on the right bank of the Fuhuan River is 5.667 km, of which the length of the ecological small slope ratio levee is 4.839 km and the building inside levee is 0.828 km. The overall layout of the project is shown in Figure 3.

The section of ecological small slope ratio levee is divided into flood control section and landscape section (see Figure 4). The width of the top of the flood levee section is 8 metres, and the inner and outer slope ratio is 1:3. When the height slope of the levee exceeds 6 metres, the inner and outer platforms shall be constructed, and they shall be appropriately widened according to the needs of stability. The width of the top of the levee in the landscape section is the same as that of the flood control section, and a slope with ratio of 1:5—1:20 is formed on the outer slope of the levee by covering soil to connect with the beach. The landscape section is built in conjunction with landscape engineering.
There are two parts of the levees in the project. The 1# part inside levee is 369 metres long, and the 2# part inside levee is 459 metres long. The typical cross section is shown in Figure 5. The building inside has two levels. The height of the first level and second level are 5.1 metres and 4.2 metres, respectively. The first underground floor is used for management rooms, and the second underground floor is used for underground garage. There are exits connecting with the road at the right and left side of the building.

The landscape project has built in the outside of levee, forming three functional areas, namely Living Area, Ecological Conservation Area, and Future Urban District. Several key landscape spots, such as Zhanggong Levee, Water Rhyme Yanbo, Riverside Flower Valley, Birds Collection, Time Reflecting, and Future Views, have been designed to integrate with the Zhanggong Levee water control culture and create bird habitats. Finally, the beach of Fuhuan River has been constructed as leisure and recreation zone, which serves for ecological protection and restoration.
Figure 3. The overall layout of the environment and ecology improvement project of the exit section of the Fuhuan River

Figure 4. Typical cross-section of urban ecological small slope ratio levee

Figure 5. Typical cross-section of building inside levee of Fuhuan River

5. Challenges of construction of urban ecological levees
There are some challenges during constructing the urban ecological levees, which have been introduced as following:
(1) Security issue. While expanding the function of the urban ecological levee, the levee becomes an open space for people gathering, which brings potential risk for flood control of the city. First, if the development and utilization of the waterfront space is not properly controlled, it will easily occupy the flood control space and affect the safety of people. Second, the increase of human activities will introduce more uncertain factors and bring potential dangers to the safety of the levee structure. Third, improper management during floods can easily cause casualties. Therefore, in the construction of urban ecological levee projects, it is necessary to strengthen flood impact assessment and analysis, strengthen the analysis of project durability, clarify relevant regulations for levee safety management, and adopt appropriate security measures.

(2) Management issue. Urban ecological levee is no longer a simple flood control project, and project management will become more complicated with the following issues. First, the operation and maintenance cost of urban ecological levee combined with landscape engineering will be higher than traditional levee. So, the traditional water conservancy project management funds will not be able to support. Second, ecological levee is no longer a pure water conservancy project management, and the management authority may involve multiple government agencies, which puts forward higher requirements for management level.

(3) The multi-disciplinary integration issue. The planning and design of ecological levees involves the integration of multiple disciplines such as water conservancy, landscape, and municipal administration, which puts forward higher requirements on the capacities of the civil engineers. In the process of planning and design the ecological levee, it usually difficult for the engineers of different professions to exchange their ideas, due to the barriers between various disciplines. How to use the advantages of multi-discipline integration still needs further exploration.

6. Conclusions and recommendations
With the deeper understanding of the concept of urban high-quality development and ecological civilization construction, the construction of urban ecological levees will be an important trend in the development of urban flood control projects in China. Ecological levees not only play flood control functions, but also contribute to the protection and restoration of water ecology and the development of its ecological service projects. Although the construction of ecological levees in cities along the Yangtze River such as Wuhan has showed positive results, the construction of ecological levees still faces challenges such as safety issues, management issues, and the multi-disciplinary integration issue. Therefore, in the process of ecological levee construction, it is necessary to strengthen the preliminary demonstration and continuously improve the relevant management mechanism.

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