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Building a Sponge City That Can Breathe

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Abstract

Drawing on Technical Guidelines for Sponge City Construction...(Trial), this study expounds on the sponge city (absorbing, storing, infiltrating, purifying and utilizing rainwater) with "one core (LID), three components, multiple objectives". Its essence is harmonizing urbanization with resources via changing traditional construction; core goals include protecting/restoring water ecology, promoting LID, transforming drainage thinking, maintaining unchanged hydrological features. The theoretical basis is BMPs, LID and Green Infrastructure. It notes China's shift to LID model, with future focuses on China-specific theories, integrating planning with smart water affairs. It offers a framework for China's sponge city and green urbanization.

Keywords

Sponge City; Low-Impact Development (LID); Water Ecological Restoration; Rainwater Management; Green Urbanization.

1. Concept of a Sponge City

According to the Technical Guidelines for Sponge City Construction – Construction of Low-Impact Development Rainwater Systems (Trial) (hereinafter referred to as the "Guidelines"), a "sponge city is a city that, like a sponge, has good 'elasticity' in adapting to environmental changes and responding to natural disasters. It absorbs, stores, infiltrates, and purifies rainwater when it rains, and releases and utilizes the stored water when needed." In essence, sponge city construction involves building a multi-objective rainwater system. By adopting modern rainwater management methods, it controls the total amount of urban runoff and runoff pollution, improves urban drainage and water logging prevention standards, realizes a virtuous cycle of urban hydrology, and maintains a sound urban ecosystem.

In summary, sponge city construction can be summarized as "one core, three components, multiple objectives, multiple approaches, multiple technologies, and the whole process." The "one core" refers to the core guiding ideology of Low-Impact Development (LID). Through decentralized and small-scale source emission reduction measures, it controls runoff and pollution, making the hydrological characteristics after development as close as possible to the natural hydrological cycle to ensure sustainable urban development. At the same time, attention should be paid to the combination of green infrastructure and gray infrastructure. The "three components" include the narrow-sense low-impact development rainwater system, the traditional rainwater pipe network drainage system, and the excessive rainwater drainage system. Through the scientific application and reasonable connection of these three systems, a resilient rainwater infrastructure system is jointly built. The "multiple objectives" are actually the true connotation of sponge city construction. It changes the rapid drainage mode of China's traditional rainwater system and proposes multiple objectives such as urban runoff total

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amount control, runoff peak control, runoff pollution control, rainwater resource utilization, and drainage and waterlogging prevention. In sponge city construction, it is necessary to accurately grasp the root causes of problems, determine control objectives with focus, and formulate design schemes according to local conditions, so as to effectively solve the increasingly prominent problems of water security, water resources, water environment, and water ecology in urban development. "Multiple approaches, multiple technologies, and the whole process" means that in the process of urban development and construction of sponge cities, a urban "sponge body" is systematically built through multiple approaches such as protection, restoration, and development. A variety of technologies such as "infiltration, storage, detention, purification, utilization, and drainage" are adopted to control runoff rainwater in the processes of source reduction, intermediate transportation, and terminal regulation, so as to minimize the damage to the original natural hydrological characteristics and water ecological environment caused by urban development and construction activities.

2. Basic Connotation of a Sponge City

2.1. Essence of a Sponge City – Resolving the Coordination and Harmony

Between Urbanization and Resources & Environment The essence of a sponge city is to change the traditional urban construction concept and realize coordinated development with resources and the environment. When the "successful" industrial civilization reached its peak, people were accustomed to the urban construction mode of conquering, surpassing, and transforming nature, resulting in serious urban diseases and ecological crises. In contrast, a sponge city follows a low-impact development mode of conforming to nature and living in harmony with it. Traditional cities carry out high-intensity development using land, while sponge cities realize the harmonious coexistence of humans and nature, land use, water environment, and water cycle. The traditional urban development model changes the original water ecology, while sponge cities protect the original water ecology. The traditional urban construction model is extensive, while sponge cities have low impact on the surrounding water ecological environment. After the completion of traditional cities, the surface runoff increases significantly, while the surface runoff can remain unchanged after the completion of sponge cities. Therefore, sponge city construction is also known as low-impact design and low-impact development.

2.2. Objectives of a Sponge City – Enabling the City to "Elastically Adapt" to Environmental Changes and Natural Disasters

First, protect the original water ecosystem. By scientifically and rationally delineating urban development boundaries and protected areas such as "blue lines" and "green lines", maximize the protection of the original ecological systems such as rivers, lakes, wetlands, ponds, ditches, forests, and park lawns, and maintain the natural hydrological characteristics before urban development.

Second, restore damaged water ecology. For urban green spaces, water bodies, wetlands, etc., that have been damaged under the traditional extensive urban construction model, comprehensively use physical, biological, and ecological technical means to gradually restore and repair their hydrological cycle characteristics and ecological functions, maintain a certain proportion of urban ecological space, and promote the improvement of urban ecological diversity. In many places in China, while addressing point-source sewage treatment, the "river chief system" has been implemented to control water pollution and improve the water ecology, achieving good results.

Third, promote low-impact development. In the process of urban development and construction, reasonably control the development intensity, reduce the damage to the original

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urban water ecological environment, reserve sufficient ecological land, appropriately excavate rivers, lakes, and ditches, and increase the water area. In addition, starting from architectural design, fully adopt green roofs, permeable pavements, constructed wetlands, etc., to promote rainwater storage and purification. According to an analysis of the 723-acre Portland Central Business District by the "Infinite Green Roofs Group" of Portland State University, converting 219 acres of roof space – one-third of the business district – into green roofs can intercept 60% of rainfall, retain approximately 67 million gallons of rainwater annually, and reduce overflow by 11% to 15%.

Fourth, effectively reduce surface runoff and mitigate the impact of heavy rains on urban operations through low-impact measures and their systematic combination.

2.3. Transforming the Thinking on Drainage and Waterlogging Prevention

The traditional municipal model holds that the more, faster, and smoother the rainwater is discharged, the better. This "rapid drainage" traditional model does not consider the recycling of water. Sponge cities follow the six-character principle of "infiltration, detention, storage, purification, utilization, and drainage", closely integrating rainwater infiltration, detention, storage, purification, recycling, and drainage, and comprehensively considering multiple objectives such as waterlogging prevention, runoff pollution control, rainwater resource utilization, and water ecological restoration. In terms of specific technologies, there are many mature process methods that can be realized through the planning, design, and spatial layout of urban infrastructure. In short, as long as the above six-character principle is effectively implemented, the annual runoff of urban surface water will drop significantly. Experience shows that under normal climatic conditions, a typical sponge city can intercept more than 80% of rainwater.

2.4. Basic Unchanged Hydrological Characteristics Before and After Development

Through the construction of a sponge city, the total runoff and peak flow can remain unchanged before and after development. Under the functions of infiltration, regulation, storage, etc., the occurrence time of the runoff peak can also remain basically unchanged. The stability of hydrological characteristics can be achieved through source reduction, process control, and terminal treatment. General Secretary Xi clearly pointed out at the 2013 Central Urbanization Work Conference: To solve the problem of urban water shortage, we must conform to nature, give priority to retaining limited rainwater, give priority to using more natural forces for drainage, and build a sponge city with natural storage, natural infiltration, and natural purification. It can be seen that sponge city construction has risen to the national strategic level.

In summary, establishing a low-impact development model that respects and conforms to nature is an effective measure to systematically solve urban water security, water resources, and water environment problems. Through "natural storage", peak shaving and regulation are realized, and runoff is controlled. Through "natural infiltration", the water ecology is restored, and the natural water cycle is repaired. Through "natural purification", pollution is reduced, water quality is improved, and a solid foundation is laid for the recycling of water.

3. Theoretical Basis of Sponge Cities

A sponge city is a new generation of urban stormwater management concept, referring to a city with good "elasticity" or "resilience" in adapting to environmental changes and responding to natural disasters caused by rainwater. Since the main theoretical basis of sponge city construction is low-impact development technology, it is also known as low-impact design and low-impact development in Europe and the United States. The concept of a sponge city first originated from Western scholars' description of the absorption of population, resources, etc.,

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by cities from surrounding rural areas or regions, and later gradually evolved to describe the relationship between cities and hydrology. Subsequently, American researchers laid three theoretical foundations for sponge city construction based on urban stormwater management research:

3.1. Best Management Practices (BMPs)

Best Management Practices (BMPs) was initially a non-mandatory policy for managing non-point source pollution in urban and rural areas of the United States. Later, it developed into a comprehensive measure for controlling urban rainfall runoff and water quality, but its core concept still remained at the terminal comprehensive management. It was first explicitly designated as the "Best Management Practice" for urban rainwater in legal form in the Federal Water Pollution Control Act in 1972.

3.2. Low-Impact Development (LID)

In the early 1990s, the concept of Low-Impact Development (LID) was gradually formed in urban stormwater management in the United States. It is a stormwater management and non-point source pollution treatment technology that starts from runoff source control and is based on restoring the natural urban hydrological system. Compared with BMPs, LID focuses more on source intervention in urban rainwater management and the application of ecological, systematic, and sustainable measures. The main concept of low-impact development is to reduce the impact of regional development on rainwater. The LID concept and technology have had a fundamental impact on urban planning and management.

3.3. Green Infrastructure

By the late 1990s, the definition of "green infrastructure" first appeared and was gradually recognized by the government. It plans, utilizes, and manages natural systems as an indispensable part of urban infrastructure, that is, "green infrastructure is the urban natural life support system, an interconnected network composed of various types of ecological land." The concept and technology of green infrastructure are not only aimed at urban hydrological management, but also for the first time incorporate natural resources as the main body of change into urban construction and management. Through planning and design technical means to restrict and guide people's use of them, it further enriches the connotation of sponge city theory.

The sponge city theory emphasizes minimizing the damage and impact of construction and development on urban natural components. At present, relevant technologies are relatively mature in urban stormwater management and water quality treatment, but their significance is not only reflected in urban water environment construction. Since the 21st century, developed countries such as Britain and the United States have further proposed the concept of "resilient cities", emphasizing the restoration and maintenance of the self-organization and self-coordination capabilities of urban systems. It expands the sponge function of urban systems to the ecological level of responding to the impact of human and natural disturbances.

4. Trend Outlook and Future Development Priorities of Sponge City Construction in China

4.1. Trend Outlook

In the long run, the construction model of China's urban rainwater system will inevitably shift to the sponge city – low-impact development rainwater system construction model. Whether it is the engineering community, academic community, or government managers, they have clearly recognized that the original single-objective, high-carbon emission, high-pollution, and extensive rainwater drainage model is unsustainable. However, based on the promotion

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experience of some countries leading in rainwater management, this transformation and the establishment of a new system are by no means an overnight task. It is a long-term and arduous systematic project. Major breakthroughs and key support must be made in management concepts, policy mechanisms, etc. A systematic basic theory, engineering and technical system, professional talent team, and new industries must be established. It is unrealistic to expect quick results in the short term. The pilot projects of sponge city construction in China are a big step forward and a leapfrog development attempt in this direction. Inevitably, deviations or even mistakes may occur. We should make sponge city construction a powerful starting point and a long-term mechanism for "Beautiful China" and future "green urbanization", give full play to its important historical role in China's urbanization and urban agglomeration construction and development, serve the grand well-being and safe environment of the Chinese people, and lay a good geographical environment and resource conditions for the great rejuvenation and prosperity of the Chinese nation.

4.2. Future Development Priorities

(1) Cities and towns are the most important sources of water pollution. Making cities the main battlefield for addressing water pollution through sponge city (LID) construction is a promising way to solve water resource shortages.

(2) The connotation of the sponge city (LID) concept is still evolving. There is a long way to go to establish sponge city theories, norms, and standards with Chinese characteristics. The Ministry of Housing and Urban-Rural Development has issued technical guidelines for sponge city construction, but this is far from sufficient. It is necessary for everyone to continuously explore and revise them in practice.

(3) Sponge city (low-impact development) planning and smart water affairs are two major systematic projects for coordinating the effective operation of each unit of a sponge city. If sponge city planning is "pushing", sponge wisdom is "pulling". The "one push and one pull" can effectively coordinate the entire sponge system, avoiding waste and information silos. Therefore, the two major systems of "one push and one pull" are very important system designs.

(4) The sponge city system should be divided into four subsystems from large to small: regional, urban, community, and architectural. These four-level systems have different focuses on low-impact development and require combined promotion of system innovation from top to bottom.

(5) According to the zoning of annual runoff total control rate, it is particularly important to establish a scientific and reasonable urban "sponge degree" evaluation system and provide incentives and guidance. Accelerate the guidance and promotion of the vigorous development of the entire sponge city, and take a healthy development path of sponge city construction with Chinese characteristics.

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