Proceedings of the 2023 International Conference on Functional Materials and Civil Engineering
DOI: 10.54254/2755-2721/26/20230856

Urban park planning and design strategies based on sponge city concept

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Abstract. In recent years, people have increasingly attached importance to the application of sponge city theory in urban planning, but often overlooked the urban water regulation role played by urban parks. This paper analyzes the connotation and relationship between sponge cities and urban parks, lists the planning principles of urban parks, and proposes design strategies for sponge urban parks. In the planning and design process of sponge urban parks, rainwater management can be optimized by facilities, vegetation planting methods can be improved, and these can be combined with the current situation of urban parks to build a strong organizational and efficient green rainwater management system. This system not only ensures the viewing effect of the garden, but also effectively recycles and utilizes natural rainwater to form a complete sponge network, effectively promoting the construction of sustainable sponge urban parks.

Keywords: sponge city, urban park, urban planning, city facility.

1. Intrduction

Sponge cities refer to a modern city that can be built like a sponge, naturally storing and purifying rainwater during periods of excessive precipitation. Following the concepts of "slow discharge, mitigation and release" and "decentralized control at the source," it reduces the burden on traditional urban drainage systems and provides them with more ecological expansion [1]. Sponge cities emphasize the rational utilization of rainwater resources during the construction process, and it is necessary to incorporate the part planning and construction into the overall urban planning and construction to form an integrated and systematic sponge city pattern [2]. Urban parks are important carriers of urban development and symbols of urban culture and ecology. The vegetation is an important component of urban green space, which can purify the air while intercepting rainwater. In the daily planning and design of urban parks, it is necessary to fully consider the issue of urban waterlogging and adjust design strategies to meet the construction needs of sponge urban parks according to local conditions [3-5]. In the process of urbanization, the design concept of urban planning and the concept of artificial transformation of the natural environment has undergone significant changes. Urban planning needs to address issues such as urban waterlogging, urban water pollution, urban water scarcity, urban water ecological degradation, heat island effect, and urban microclimate, to establish a balanced relationship between urban construction and ecosystems [6].

In recent years, people have increasingly attached importance to the application of sponge city theory in

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urban planning, but often overlooked the urban water regulation role that urban parks can play due to their large proportion in urban green spaces and water bodies. Based on the basic principles of sponge city design and planning, Yang proposed that the development difficulties of modern residential planning in China should be fully summarized under the background of water ecological civilization construction. Optimizing the planning and design of residential areas through methods such as repairing aquatic ecological species, which neglects the sponge ecological regulation ability of residential parks [7]. Han stated that effective utilization and recycling of natural rainwater to promote the establishment of a rainwater recycling system and the construction of urban gardens, emphasized the effective regulatory role that urban parks can play in sponge city planning [8]. However, it only explores the ecological park part of urban parks and is not comprehensive and profound enough.

This paper is mainly based on the methods and strategies of sponge cities to solve urban water problems, using nationally designated planning standards as guidelines. To solve problems such as urban waterlogging, urban water pollution, and urban water scarcity, efforts are made to build environment-friendly, resource-saving and public-shared urban parks, and provide planning and design strategies.

2. Sponge city and urban park

2.1. The connotation of sponge city

In the "Technical Guidelines for Sponge City Construction (Trial Edition)" released in China, it is clearly stated that a sponge city refers to a city that has good "resilience" in adapting to environmental changes and responding to natural disasters, like a sponge. When it rains, it absorbs, stores, seeps, and purifies water. When needed, the stored water is released and utilized [9]. In the process of urban construction, there are several common water problems. The first problem is urban waterlogging, which is a disaster phenomenon caused by the short-term accumulation of large amounts of rainfall and runoff, affecting the normal operation of urban functions and causing losses. The second issue is urban water pollution, as the amount and speed of pollution discharge exceed the capacity and speed of self-purification of urban water bodies. The third issue is urban water scarcity, mainly due to the demand and use of water in urban economic and human living activities exceeding the maximum amount of water that the city can provide. Sponge cities have good water regulation capabilities and can systematically solve water environment and ecological problems with cross scale and cross regional characteristics.

In the construction process of sponge cities, it is necessary to pay attention to urban greening, carry out wetland protection, collect rainwater by installing rainwater collection devices within the city, demolish a large area of cement pavement and replace it, consider the natural discharge of rainwater in the urban design process [10-12]. The purpose of building sponge cities is to alleviate the drainage pressure of the city, improve the utilization efficiency of water resources, increase the green coverage rate of the city, and improve the ecological environment of the city.

2.2. The connotation of urban parks

The "Classification Standard for Urban Green Space" defines park green space as a green space that is open to the public, primarily for recreational purposes, and has functions such as ecology, beautification, and disaster prevention [13]. The existence of urban parks is an ecological and environmental issue, as well as a socio-economic issue that affects the quality of urban spatial development. With the continuous development of the economy, society, and urbanization, the connotation, type, and carrying functions of parks are constantly enriched, becoming an important spatial carrier for cities to adapt to living, work, and entertainment needs. The planning of urban parks is closely related to urban equity and has gradually become one of the important ways to shape and coordinate urban land use structures and functional clusters.

2.3. The relationship between sponge city concept and urban park planning

The main significance of building a sponge city is to solve the urban water problem. Besides, there are also derived problems such as urban water ecological degradation, heat island effect, and urban microclimate. However, these three can be alleviated or solved by solving urban waterlogging, urban

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water pollution, and urban water shortage [3]. The existence of urban parks determines that large areas of green space and water bodies can be reasonably constructed within the city without affecting other urban functional zones and infrastructure. Green spaces in cities have the function of purifying water bodies.

In cities, there are main sources of water pollution such as industrial wastewater, domestic sewage, and precipitation runoff. Industrial wastewater and domestic sewage are mostly discharged through pipelines in cities, making them easier to treat and purify in a centralized manner. However, atmospheric precipitation forms surface runoff, which washes away and carries away a large amount of surface pollutants. Its composition and water flow direction are difficult to control, and many of them seep into the soil and continue to pollute groundwater. Many aquatic and biogas plants have a significant effect on purifying urban sewage. For example, in ponds with reeds, the suspended solids, chlorides, organic nitrogen, phosphates, and ammonia in the water are significantly reduced. In addition, grasslands can retain a large number of harmful metals, and absorb surface pollutants, and the roots of trees can absorb dissolved matter in water, reducing the bacterial content in the water. The water bodies in parks, as one of the main components of urban water bodies, can help restore wetland ecosystems and have the function of flood storage and water storage. Using the concept of the sponge city to collect and utilize natural water resources, reduce surface runoff, enhance water storage capacity in the park, alleviate rainy season floods and dry season droughts, and build ecological urban parks are of great significance for environmental protection and urban development and construction.

3. Principles of urban park planning

The basic functions of urban parks include ecological functions, aesthetic functions, leisure and entertainment functions, protection and education functions, disaster prevention and risk avoidance functions, etc. The planning of urban parks needs to meet four principles.

3.1. The principle of sociality

Urban parks have evolved from closed private courtyards to urban open spaces throughout society, representing the reform of modern urban construction concepts and reflecting society's concern for human nature and satisfaction with people's spiritual life. Urban parks are one of the infrastructures of urban construction and have significant social benefits that cannot be ignored. Therefore, the planning and design of urban parks should be aimed at creating a relatively free and equal social activity space for all social classes and groups, belonging to social public spaces. The overall planning and design of urban parks should make reasonable use of space to create different areas with rich functions, including entrances, management, rest, sports construction, entertainment activities, sightseeing and other related functional areas, and strive to plan exclusive spatial environments that meet the needs of different groups of people.

3.2. Principles of ecology and sustainability

Urban parks not only provide comprehensive social spaces for residents, but also have many ecological functions, such as the natural function of rainwater infiltration and storage, which can alleviate urban waterlogging, reduce the load of urban runoff, and play an important role in protecting the urban ecological environment and improving urban climate. Therefore, when planning and designing urban parks, special ecological design should be carried out based on the regional runoff indicators and in combination with the landscape requirements and natural conditions within the urban parks. Attention should be paid to the ecological effects within the urban parks, and spatial resources should be fully utilized to establish multi-level, multi-structured, and multi-functional scientific plant ecological communities, forming a long-term healthy coexistence ecosystem. Adhering to the green development ecological design concept of protecting the environment and saving resources, coordinate the relationship between urban parks and the surrounding environment, urban construction, and development.

3.3. The principle of adapting to local conditions

From a macro perspective, the planning and design of urban parks should be coordinated with urban

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planning and design, regional cultural atmosphere, and achieve external coordination and internal unity. From a micro perspective, the planning and design of urban parks should be coordinated with the terrain, transportation, architectural style, environmental colors, etc. of the site. On the one hand, the planning and design are based on the local climate and natural conditions, and on the other hand, the regional traditional historical culture, local customs, and cultural values are fundamental. In the planning and design of landscape plants, priority should be given to local plants. In architectural design, local stones should be used to protect existing historical relics, precious animals and plants, and local culture and characteristics should be inherited and disseminated. In the planning and design process, the terrain should be fully utilized and reasonably transformed to achieve the effects of engineering rationality, safety, economy, and aesthetics.

3.4. The principle of safety

Urban parks are frequently visited by the public, and planning safety work within the park is an important guarantee for improving the quality of residents' outdoor activities experience. Corresponding warning signs can be set up to serve as warnings, such as setting up anti falling warnings in water areas and setting up fire and anti-theft warnings in corresponding places. Road planning and design should consider the convenience of special people’s use, combining the spatial layout with road lighting to plan and reduce crime rates and consider the design of emergency areas to ensure smooth and unobstructed routes. Moreover, detailed specifications for the use, precautions, and maintenance time of urban park facility labels should be developed, and the design of buffer strips to reduce accidents, etc. should be considered. In addition to paying attention to creating a sense of security in environmental design, it is more important to create safe and reasonable park management measures to ensure the safe production of urban parks in operation.

4. Design strategy for sponge city parks

4.1. Green space design strategy

Firstly, planting vegetation with well-developed root systems and strong interception ability. The selected plants not only need to prevent the loss of soil and water resources, but also need to increase the soil's permeability, reduce the water flow rate, improve the soil's ability to filter, intercept, and absorb surface runoff, sediment, nutrients, and organic matter, and reduce the concentration and toxicity of pollutants in the water body. They are the first barrier to water purification. Willow, spruce, walnut, wisteria, kudzu vine, white sandalwood and other plants have deep and fast root systems, which are not prone to pests and diseases, making them suitable for planting.

Secondly, planting vegetation with strong resistance to soaking and rainwater retention.In the frequent occurrence of extreme weather, the soaking resistance and rainwater collection capacity of vegetation should be fully utilized, and sponge green spaces can be used instead of pipelines to collect rainwater. Sponge green spaces are divided into three levels from top to bottom: canopy retention, topsoil infiltration, and rhizosphere retention. The higher the height of a tree, the greater its canopy density and leaf density, and the stronger its rainwater collection ability. Cedar pine, sycamore, and other trees are not suitable for planting due to their fear of water, while the roots of trees such as metasequoia, fir, and pond fir are more resistant to water and suitable for planting.

Thirdly, planting suitable vegetation for cooperative planting.The vegetation in urban parks needs to fully consider biodiversity to improve survival rates. Based on ensuring that plants can adapt to the local environment for growth, the ornamental value of plants can be comprehensively considered, combined with co-growing plants, to promote the growth of the park's water conservation capacity and water purification capacity.

DOI: 10.54254/2755-2721/26/20230856

4.2. Stormwater management design strategy

4.2.1. Improve the natural permeability of rainwater. The available sponge facilities include sunken green spaces, permeable paved roads, etc. A sunken green space refers to a public green space with an elevation lower than the surrounding road surface, also known as a low-rise green space. It can be understood as an ecological green space with lower terrain, which can regulate and store volume, purify rainwater runoff, collect surrounding surface rainwater runoff, and alleviate runoff peaks by accumulating and sinking rainwater. Contrary to the concept of "flower beds", the concept of the sunken green spaces is to use open spaces to receive and store rainwater, to reduce the discharge of runoff. Low-rise green spaces have certain requirements for the depth of the depression, and their soil quality is often not improved. Compared with the "linear" vegetation of shallow gullies, the main feature is that the "surface" can absorb more rainwater, and the internal plants are mainly composed of local herbs.

Permeable pavement is one of the typical low-impact development technologies used for road surface construction in sponge cities. It has a rough surface and strong permeability. Its multi-layer pore structure can effectively absorb rainwater, reduce peak flow, achieve the regulation and storage function of urban water circulation, and alleviate the urban heat island and rain island effects. The functions of permeable pavement include reducing the impermeable area of urban surfaces, eliminating accumulated water, reducing noise, preventing slip, cooling, and preventing waterlogging. The surface materials for permeable pavement generally include permeable bricks, permeable concrete, and permeable asphalt. The base material is generally graded crushed stone. The cushion material is usually gravel or loose soil to meet the permeability, bearing capacity, and frost heave degree of the cushion material.

4.2.2. Collect trapped rainwater. The urban park design based on the concept of the sponge city combines the original terrain and landforms with the reasonable design of rainwater management facilities, such as plant ponds, rainwater gardens, reservoirs, etc. In local design, attention should be paid to the slope and aspect of the "sponge body" terrain to rationalize the connection of the landscape. Designing a green drainage system on the roof, which collects rainwater from the roof into a water storage tank and then irrigates the vertical stepped ecological flower bed below through a transmission pipeline. The flower bed area retains and purifies the rainwater that seeps down. The purified rainwater, along with the rainwater that seeps down from the permeable pavement, enters the lower reservoir through the rainwater collection pipeline and is stored as park water. The arrangement and circulation structure of rainwater management in different regions are different. When the terrain of the reservoir is low and the terrain of the grass planting ditch is high, the rainwater transmission pipeline and water pump should be installed in combination. The excess water from the reservoir can be used to irrigate plants at high altitudes. The distribution arrangement of sponge bodies in the park should consider the terrain and the collection and purification capacity of rainwater management facilities, as well as the reasonable combination of distribution density and water purification intensity to achieve the overall optimization of rainwater management. The degree of rainwater purification should meet the water use standards of the park to avoid causing water pollution.

4.3. Wetland design strategy

The design of wetland water bodies is a very effective measure in the construction of urban parks. The wetland in the park is divided into a waterfront area, water surface area, shallow water area, and deep-water area according to different water depths. Rainwater and artificial water storage are drained and graded by different levels of water storage areas to form top-down drainage zones and different types of water landscapes, meeting the landscape role that urban parks should have.

In the wetland of the park, different types of plants are paired to form a clear landscape layer, which is gradually connected layer by layer by waterfront plants, emergent plants, phytoplankton, and submerged plants, enhancing the overall viewing effect of the park wetland.

4.4. Recreational facilities strategy

Boating experience can be designed for sponge city parks. There is a planned yacht dock in the water

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area, equipped with wooden hand rowing boats, water bicycles, sailboats, and other projects, allowing tourists to appreciate the plant configuration and wetland landscape in the park while boating on the island, bringing a different psychological satisfaction from land-based viewing.

Popular Science Education Design. Designing a water fall area in the park to enhance the sense of spatial hierarchy, designing a wooden plank path for tourists to walk on, and creating a reminder board for the main aquatic plant species and characteristics, which is arranged near the plank path. These strategies enable tourists to have a better understanding of aquatic plants and ecological water circulation systems while enjoying the landscapes constructed by aquatic vegetation, thereby creating a landscape experience that integrates leisure and recreation, science education, and ecological protection.

Design of Children's Rest Area. The children's rest area is designed in conjunction with the grassy slope terrain of the covered building and the shallow streams of the rainwater garden, forming an enclosure structure with the outside world, ensuring the safety of children's entertainment while ensuring the internal landscape of the park.

4.5. Road design strategy

Road vegetation landscape design should reasonably utilize when planning road land, to scientifically expand urban green space, and reduce the road area of landscape gardens. Simultaneously the consistency between the planned area and drainage requirements of the green space system should be maintained. Using highly dispersed, coherent, and dense green plants to replace high-density plants on both sides of the road.

When designing roads, building materials should be selected based on the principles of sponge cities. Paving materials with diverse functions, excellent performance, and excellent permeability should be selected to maximize the quality, collection, and runoff of rainwater in landscape gardens. At the same time, to achieve the purpose of filling grass and paving grass bricks, a certain gap is reserved on the road surface.

5. Conclusion

This paper analyzes the connotation and relationship between sponge cities and urban parks, lists the planning principles of urban parks, and proposes design strategies for sponge urban parks. To build a sponge city with natural permeability, air purification ability, and moisture absorption function, the construction of urban parks should adapt to the sustainable development of the city. In the planning and design process of sponge urban parks, optimizing rainwater management facilities, improving vegetation planting methods, and combining with the current situation of urban parks, building a strong organizational and efficient green rainwater management system can not only ensure the viewing effect of gardens, but also effectively recycle and utilize natural rainwater, forming a complete sponge network, effectively promoting the construction of sustainable sponge urban parks. The planning and design strategies for sponge urban parks mentioned in this paper need to be combined with specific urban planning projects in the future, tailored to local conditions, and developed more convenient and reasonable park planning and design strategies.

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