

Optimization of Urban Pocket Park Landscape and Benefit Evaluation Analysis under the Concept of Sponge City

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Abstract: During the process of urbanization, the proportion of urban hard surfaces has gradually increased, and problems such as urban flooding, heat island effect, and waste of rainwater resources have become increasingly prominent. Establishing a sponge city is an important measure to improve the urban water environment. Pocket parks are small open green spaces in high-density urban areas, characterized by dispersed layout, small service scope, and flexible construction and renovation. They are an important micro-means to achieve the goal of sponge city construction. This paper analyzes the conceptual connotations and internal connections of sponge city and pocket parks, and explains the landscape improvement methods from aspects such as vertical design, permeable paving, rain garden creation, plant community configuration, and dry stream storage facilities. A multi-dimensional comprehensive benefit evaluation model combining ecological, economic, and social aspects is established. The research shows that sponge-type pocket parks can simultaneously achieve multiple functions such as rainwater control, environmental restoration, and public recreation, providing a theoretical basis for the planning and renovation of small green spaces in the context of urban renewal.

1. Introduction

Domestic urban construction has shifted from large-scale incremental development to the renewal of existing facilities. There are more and more hardened pavements in the built-up areas, and the natural hydrological cycle of the original sites has been artificially disrupted. During extreme rainfall, urban rainwater flows rapidly into the municipal drainage system, not only increasing the possibility of flooding, but also directly discharging pollutants such as suspended solids and nutrients from the road surface into the water body, thereby increasing the pressure on the urban water environment. The natural recharge process of groundwater is also suppressed in the built-up areas where land resources are relatively scarce. In these built-up areas with limited land resources, large-scale construction of comprehensive parks is restricted by the land conditions. Pocket parks, which utilize urban edge spaces and road setback areas for construction, can compensate for the insufficient green space supply near communities^[1]. Currently, some

sponge-type pocket park projects still have the problem of technical and landscape separation. The sponge facilities are merely superimposed as engineering modules without integrating with the overall landscape system, and the evaluation standards for the benefits of small green spaces are not clear enough. The project effectiveness is mainly judged based on subjective feelings, which is not conducive to the promotion and improvement of the technical model. Based on the above actual situations, this paper discusses the landscape optimization methods of sponge-oriented pocket parks, establishes an implementable comprehensive benefit evaluation model, and provides a theoretical basis for the renovation and upgrading of small green spaces.

2. Related Concepts and Theoretical Basis

2.1 Concept and Core of Sponge City

The core of the sponge city lies in enhancing the city's resilience to changes in the rainwater environment. The construction practice needs to implement the overall technical concept of infiltration, storage, purification, utilization, and drainage. Various green spaces and permeable facilities can promote rainwater infiltration, depressions and storage spaces can complete temporary rainwater storage, and the synergy of soil, plants, and microorganisms can achieve runoff purification. The treated rainwater resources can be used for site greening irrigation, and a complete drainage system needs to be provided during the construction process to ensure the safe discharge of excessive rainwater during heavy rainfall^[2]. Low impact development is the core technical logic of sponge city construction. This concept emphasizes retaining the hydrological characteristics of the site before development to the greatest extent, and using decentralized and small-scale facilities to complete rainwater control. This is different from the traditional municipal engineering construction approach that focuses on rapid drainage. It can also balance multiple goals such as water ecological restoration and landscape creation.

2.2 Concept and Characteristics of Pocket Parks

Pocket parks belong to small urban public green spaces. Their construction sites are mostly fragmented idle spaces in the city, with an area range mostly between 400 and 10,000 square meters. The service radius is controlled within 300 to 500 meters. The spatial layout of pocket parks presents a fragmented characteristic. Construction will make full use of street corners, abandoned plots, and green belts on both sides of roads to achieve green construction in urban gaps. Their service objects are mainly residents in the surrounding communities, and the high walkability can frequently meet the residents' short-term leisure, fitness, and social interaction needs, which can compensate for the blind areas of large parks in service coverage. The functions of pocket parks have strong plasticity. The design can combine the actual conditions of the site to add different functions such as cultural display, children's activities, and rainwater storage, thereby forming differentiated micro-green space.

2.3 Coupling Logic of Sponge City and Pocket Parks

From the perspective of sponge city construction, pocket parks are widely distributed, and each micro-green space can form a distributed rainwater treatment unit. The soil and plant communities of the green spaces can provide material carriers for rainwater infiltration, retention, and purification. The coordinated operation of a large number of pocket parks can share the drainage pressure of the municipal drainage network in the area. From the perspective of pocket park construction, rain gardens, dry streams, and other sponge facilities themselves have corresponding

landscape value, which can enrich the landscape hierarchy of the site and improve the situation where the proportion of hard landscape in traditional pocket parks is too high.

3. Optimization Strategies for Pocket Park Landscapes under the Sponge City Concept

3.1 Vertical Design Optimization

The vertical conditions of the site directly affect the flow direction of rainwater and also influence whether various storage spaces can function effectively. When conducting terrain modification, it is necessary to follow the natural water collection patterns and set up an overall gentle slope ranging from 0.3% to 5%. The paved surface-generated surface runoff should be guided to the green area, and the green area's ground should be lowered by 50 to 200 millimeters compared to the surrounding paved areas, thereby forming a depressed space with water collection capacity^[3]. The design needs to combine the original terrain of the site to divide different water collection units and provide corresponding rainwater collection and overflow channels for each unit, in order to prevent the mutual flow of rainwater from different areas from causing surface erosion and reducing local water accumulation and soil erosion problems.

The low point of the site needs to be equipped with an overflow outlet. When the rainfall exceeds the facility's storage capacity, the excess rainwater can be discharged into the municipal drainage system. The height of the overflow outlet needs to be 100 millimeters higher than the designed water storage level, in order to balance the normal landscape effect and the safety of stormwater drainage. Vertical renovation also needs to implement relevant accessibility design regulations. Main access paths should remain gentle, and the slope of the low areas should be treated with softening measures to avoid potential safety hazards caused by steep slopes and deep pits.

3.2 Optimization of Permeable Paving System

Hard paving is the main source of rainwater runoff in pocket parks. The core focus of the permeable paving renovation is to reduce surface runoff and guide rainwater to infiltrate locally. Square and pedestrian paths should prioritize the use of permeable bricks, permeable concrete, etc., with a paving permeability coefficient not lower than $1.0 \times 10^{-3} \text{m/s}$. A 1% to 2% cross slope should be set on the paving surface, and flat kerbs or kerb openings should be set at the connection position between the paving and the green area to ensure that the surface rainwater can smoothly flow into the green area's sponge facilities.

The lower layer of the permeable paving is laid with a 200 to 300 millimeter graded gravel storage layer to extend the rainwater retention time and improve the infiltration efficiency. Permeable paving is not suitable for all construction sites. In areas with high groundwater levels, heavy soil layers, and dense underground pipelines, the layout range of permeable paving should be controlled, and additional rainwater drainage structures should be added to prevent underground water accumulation from damaging the paving structure and pipeline operation safety. The paving materials should also meet the requirements of slip resistance and wear resistance to adapt to the usage needs of the elderly and children.

3.3 Optimization of Rain Garden and Inverted Green Spaces

Rain gardens and inverted green spaces are the core storage and purification units of the sponge pocket park and also undertake the important function of landscape display. Rain gardens are divided into a water storage layer, a covering layer, a planting soil layer, a sand filter layer, and a gravel drainage layer from top to bottom. The water storage depth is controlled at 100 to 300

millimeters, and the thickness of the planting soil layer needs to be adjusted according to the specific type of planted plants. The thickness of the soil layer for herbaceous plants is 300 to 600 millimeters, and the thickness of the soil layer for shrub planting areas is 600 to 1000 millimeters. The slope of the rain garden edge should not be greater than 1:3. At the runoff entrance, a gravel buffer zone should be set to reduce the rainwater flow rate and achieve sediment pre-precipitation, reducing the risk of blockage of the internal fill materials. During the planning layout stage, rain gardens should not be treated as isolated engineering nodes. The design needs to be coordinated with the paths, rest benches, and landscape stones to transform the storage space into a landscape node with ornamental value^[4].

3.4 Optimization of Plant Configuration

The plant community is an important carrier for the sponge facilities to achieve runoff purification and rainwater interception, and it directly determines the overall landscape quality of the pocket park. The plants inside the sponge facilities need to adapt to the alternating growth environment of intermittent flooding and drought. Species selection should prioritize native resistant species. The design should abandon the single lawn construction model and build a multi-layer plant community composed of trees, shrubs, herbaceous plants, and ground covers. The upper layer of trees can utilize their canopies to retain rainwater, reducing the erosion effect of raindrops on the surface soil. The middle layer of shrubs can enrich the spatial hierarchy. The lower layer of perennial ground cover and ornamental grasses can achieve both water purification and seasonal landscape effects. The existing well-growing trees in the site should be retained, as they can provide habitats for insects and small birds to enhance the biodiversity of the site and also reduce the maintenance costs in the long run. The plant selection should be combined with the site's hydrological conditions for differentiated layout. Low-lying water collection areas should use species that can tolerate flooding, while areas with higher terrain should use drought-tolerant species. This will improve the overall survival level of the community.

3.5 Optimization of Dry Creek and Storage Facilities

For pocket parks with abundant rainfall or limited ground space, dry creeks and underground storage facilities can serve as effective supplements to the sponge system. The dry creek simulates the overall terrain of a natural stream. Under normal conditions, it can serve as a dry landscape feature. During rainfall, it can undertake the functions of rainwater transportation and temporary storage. The creek bed is constructed using gravel and boulders in a natural manner, with a curvy and variable shoreline. Local areas are dotted with hydrophilic plants to enhance the landscape expression.

When the available space on the ground is insufficient, modular underground water storage units or underground storage tanks can be used. The ground area is restored to a lawn or activity area, and the purified rainwater can be used for site greening irrigation, thus completing the utilization of rainwater resources. Underground storage facilities must reserve maintenance and dredging channels. The accumulation of fill material will significantly weaken the storage capacity over a long period of operation. Adequate maintenance conditions are an important prerequisite for the facilities to continuously achieve their benefits.

4. Construction of the Benefit Evaluation System for Sponge-Type Pocket Parks

4.1 Framework of the Evaluation System

The actual benefits brought by sponge-type pocket parks cover multiple aspects such as ecology, economy, and society. Based on the aforementioned characteristics, this paper establishes a hierarchical benefit evaluation framework. Considering that pocket parks generally have limited scales and some sites are difficult to conduct continuous monitoring, the indicators selected are fully in line with the actual conditions of small-scale green spaces. The evaluation content includes quantitative data obtained through on-site measurement and qualitative information obtained from on-site investigations. This framework can be used both in the early planning stage of the project for horizontal comparison of multiple alternative design schemes, and after the project is completed and put into use, to test the actual effects produced by the project implementation.

4.2 Ecological Benefit Indicators

The output at the ecological level is a key focus of sponge-type pocket park construction. The evaluation content mainly focuses on the rainwater regulation of the site and the improvement of the surrounding environment. The runoff reduction effect needs to refer to the annual runoff total control level and the runoff reduction situation during a single rainfall process. Affected by the proportion of internal green spaces, the storage capacity of rainwater by pocket parks is generally higher than that of completely hardened urban areas. The pollutant reduction level can reflect the purification effect of various sponge facilities on pollutants such as SS, COD, TN, and TP in the runoff. Relevant practical data show that rain gardens can remove 70% to 90% of suspended solids SS and have a removal effect of approximately 30% to 60% for COD. The shading effect of vegetation and transpiration cooling can also regulate the local climate around the site. Within the pedestrian activity area, a temperature reduction of 1 to 3 degrees Celsius can be achieved.

4.3 Economic Benefit Indicators

The economic benefits of sponge pocket parks can be divided into direct benefits and indirect benefits. The revenue from rainwater resource utilization belongs to direct benefits. The collected rainwater can replace tap water for greening irrigation, and for a 2000-square-meter pocket park as a reference, the project can reuse hundreds of cubic meters of rainwater each year, thereby saving water supply costs. The reduction in the burden of the drainage system comes from the reduction in the volume of rainwater entering the pipe network due to the source reduction of rainwater brought about by sponge facilities. These changes can reduce the overall investment in pipe network expansion, pump station operation, and other aspects, as well as reduce various economic losses caused by urban flooding. Land appreciation belongs to typical indirect benefits. The environmental improvement brought by pocket parks will boost the value of surrounding plots and residential properties. Cost analysis can reveal that sponge renovations will slightly increase the initial construction investment, but when viewed from the perspective of the entire life cycle and considering factors such as comprehensive operation and maintenance, disaster losses, etc., the overall economic cost of the project is feasible.

4.4 Social Benefit Indicators

Social benefits focus on the comprehensive value brought by public spaces to residents and the city. The recreational service value is reflected in the project providing nearby outdoor spaces for

residents to engage in leisure, exercise, and social activities, helping to improve residents' living quality. The ecological education value comes from the educational attributes of sponge facilities, and the accompanying explanatory signs can popularize rainwater management knowledge to the public. The urban landscape demonstration value is reflected in the optimization of the overall appearance of the area brought by the project, and it can also form a replicable model for the construction of small-scale green spaces. The public health benefits come from the promotion of outdoor activities by the open green space, which can relieve psychological stress and improve residents' physical and mental health levels.

5. Conclusion

Pocket parks and sponge city construction have a natural coupling foundation. In the context of urban stock renewal, by adopting a comprehensive design that includes vertical topography, permeable paving, rain gardens, plant communities, and storage facilities, it is possible to prevent the simple accumulation of sponge facilities and integrate the rainwater management function into the overall landscape model of pocket parks, achieving the coordinated development of ecological functions and recreational services. In the future, as urban renewal continues to advance, it can promote the linkage between scattered sponge pocket parks and the regional rainwater drainage system, fully leveraging the practical role of small green spaces in enhancing the resilience of the urban water ecosystem and improving the living environment.

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