

Study on the Integrated Design of Residential Landscape and Architecture Based on the Sponge City Concept

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Abstract:

With the acceleration of urbanization, ecological and environmental problems such as urban waterlogging and water shortage have become increasingly prominent. The sponge city concept provides an effective solution to these issues. As the basic unit of a urban ecology, the coordinated design of landscapes and buildings is an important part of sponge city construction. From a professional architectural design perspective, this paper conducts an in-depth study on the integrated design of residential landscape and architecture based on the sponge city concept. On the basis of clarifying the core connotation of the sponge city and the characteristics and internal connections of integrated design, specific design strategies are proposed from four dimensions: site planning, building ontology, landscape facilities, and operation and maintenance management, which are verified and analyzed with practical cases. The results demonstrate that the proposed integrated design strategy is capable of reducing the rainwater runoff coefficient of residential areas to approximately 0.3–0.4, while achieving a rainwater purification rate of over 80%. This approach has notably enhanced the rainwater regulation capacity and ecological quality of residential areas, offering theoretical support and practical guidance for the sustainable design of residential developments under the framework of sponge city initiatives.

Keywords:

Sponge City, Residential Area, Landscape Design, Architectural Design, Integrated Design

1. Introduction

Under the dual pressures of global climate change and the rapid advancement of urbanization, the imbalance of the urban hydrological cycle has become increasingly severe. Phenomena such as frequent waterlogging disasters and intensified contradictions between water supply and demand have become prominent bottlenecks restricting the sustainable development of cities. The discrete model of “architecture-oriented and landscape-supplementary” in traditional residential design not only results in the functional separation of landscape and architecture but also renders residential areas severely deficient in rainwater regulation, storage, and purification capacity. Impervious pavements and sealed rooftops block rainwater infiltration, while limited green spaces lack systematic rainwater management functions—ultimately creating a governance dilemma of recurrent waterlogging during rainfall

and rapid droughts thereafter, which runs counter to the green and low-carbon urban development goals. As the core carrier of sponge city construction, the integrated design of residential district landscape and architecture aims to break the functional separation between the two, and achieve in-depth coordination of spatial layout, functional benefits and ecological efficiency. Based on this, the research in this paper is intended to provide a feasible scheme for improving the rainwater management capacity of residential districts and building an ecologically livable living environment, which holds important practical significance for promoting the ecological transformation and sustainable development of cities.

2. Research Methods for the sponge city Concept and the Integrated Design of Residential District Landscape and Architecture

2.1. Research Model

A standard research model of “theoretical construction - scheme design - empirical verification” is adopted. Firstly, a theoretical framework for integrated design is constructed based on the sponge city’s core theory of “infiltration, retention, storage, purification, utilization and discharge” and relevant theories of residential district planning and design. Secondly, combined with the actual needs of residential districts, specific design schemes for four dimensions (site planning, building ontology, landscape facilities, and operation and maintenance management) are formulated. Finally, the feasibility and effectiveness of the design schemes are verified through practical cases.

2.2. Monitoring Methods

A multi-dimensional monitoring system is established in the case project, including the following specific aspects:

Hydrological monitoring: Rain gauges, flow sensors and water level monitors are installed at key nodes such as the source, process and end of drainage zones and reservoirs to collect real-time rainfall data, rainwater runoff flow, and reservoir water level changes.

Environmental monitoring: Temperature and humidity sensors and air quality monitors are placed around buildings and in green spaces to monitor changes in the microclimate and air quality of the residential district.

Facility performance monitoring: The permeability coefficient of permeable pavement, the fertility and permeability of planting soil in rain gardens, and the water quality of reservoirs are tested regularly, using a combination of on-site sampling with professional testing equipment and laboratory analysis.

2.3. Data Sources

Basic data: Site topographic slope, soil type, permeability coefficient, etc., are obtained from on-site surveys and laboratory tests; historical rainfall data are sourced from the public database of the meteorological department where the project is located.

Monitoring data: Real-time hydrological, environmental and facility performance data are acquired through the above monitoring methods, with a monitoring cycle of 1 year.

2.4. Case Design Process

Preparatory work: Conduct on-site surveys, collect basic data, and clarify the sponge city construction goals and functional needs of the residential district for the project.

Scheme design: Based on site conditions and target requirements, carry out drainage zoning division and spatial function adaptation, and design specific sponge measures for building ontology and landscape facilities.

Construction implementation: Cooperate with the construction unit for technical disclosure, track the construction process to ensure the accurate implementation of the design scheme, and solve problems arising during construction in a timely manner.

Monitoring and optimization: Launch monitoring work after the project is completed, continuously collect data, optimize the operation and maintenance management scheme according to the monitoring results, and summarize design experience.

3. Core Connotation of the Sponge City Concept

The core of the sponge city concept is to adhere to the principle of ecological priority, combine artificial measures with natural ecosystems, and realize the integrated management of urban rainwater through “infiltration, retention, storage, purification, utilization, and drainage” (Figure 1). Its specific core connotations include three aspects: first, low-impact development, which minimizes the impact of urban development on the natural hydrological cycle. Through decentralized small-scale rainwater management facilities such as rain gardens, permeable pavements, and grassed swales, on-site infiltration, retention, and utilization of rainwater are achieved. Second, ecosystem service functions, which give full play to the rainwater regulation and storage, purification, and water resource circulation functions of natural ecological spaces such as urban green spaces, wetlands, and rivers, so as to improve urban rainwater regulation capacity and ecological environment quality [1]. Third, sustainability, which focuses on long-term benefits and sustainable development. Through reasonable planning, design, management, and operation, the recycling of rainwater resources is realized, the dependence on traditional water resources is reduced, the risk of urban waterlogging is lowered, and the coordinated development of urban ecology, economy, and society is promoted [2].

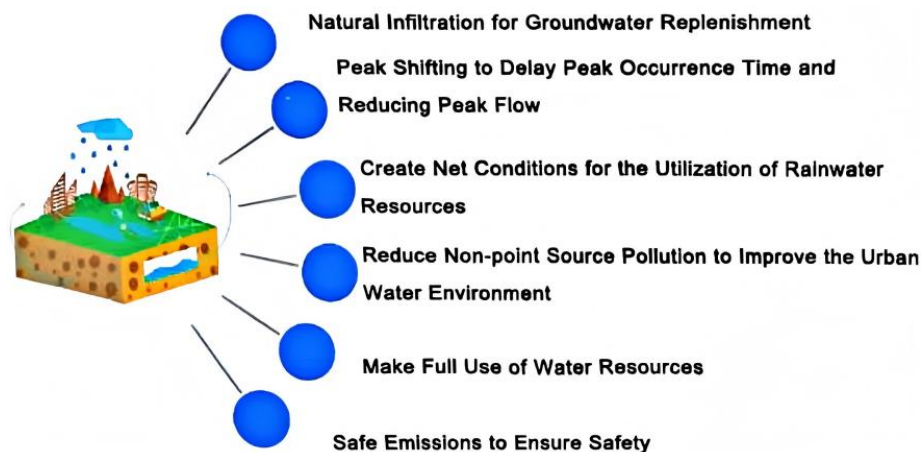


Figure 1. The sponge city concept.

4. Integrated Design Strategies of Residential Landscape and Architecture Based on the Sponge City Concept

Based on the core requirements of the sponge city for “infiltration, retention, storage, purification, utilization, and drainage” and the triple needs of residential areas for “ecology, life, and safety”, it is necessary to construct a complete design scheme from four dimensions: site planning, architectural design, landscape facilities, and operation and maintenance management, so as to realize the in-depth coordination of landscape and architecture and the organic unity of function and ecology[3,4]. The specific design schemes are as follows:

4.1. Site Planning: Constructing a "Sponge-Priority" Spatial Layout System

Site planning is the foundation of the integrated design of residential landscape and architecture under the sponge city concept. It needs to take the natural hydrological conditions of the site as the core and create a spatial pattern compatible with sponge functions through a three-step method of “terrain reconstruction - drainage zoning - functional adaptation”.

In the early stage of design, detailed site surveys should be carried out to obtain key parameters such as terrain slope, soil infiltration coefficient, and historical rainfall data. For example, in mountainous sites with large slopes, the original natural catchment spaces such as gullies and depressions should be retained to avoid large-scale earth excavation. In clay areas with weak soil infiltration capacity, sand cushions or crushed stone blind ditches should be added to improve rainwater infiltration capacity [5,6].

The division of drainage zones follows the principle of “small catchment, large circulation”. The residential area is divided into several independent drainage zones, each with an area controlled at 1-2 hm² to ensure on-site rainwater treatment. The boundaries of the zones are naturally separated by roads and building groups. Each zone constructs a three-level rainwater management system of “source - process - end”: the source initially collects rainwater through building roofs and road pavements; the process guides rainwater transmission through grassed swales and permeable pavements; the end realizes rainwater retention and utilization through rain gardens and reservoirs, forming a closed-loop rainwater management system.

In the functional space adaptation link, it is necessary to deeply integrate sponge functions with residential functions. Buildings adopt a “staggered” layout to reserve space for landscape sponge facilities, and the building base is raised to a certain height to avoid rainwater backflow. In the road system, the main road adopts a cross-section of “carriageway + grassed swales on both sides”, the carriageway uses permeable asphalt, and the sidewalk uses permeable bricks[7,8]. The green space rate should be $\geq 35\%$, of which sponge-type green space accounts for $\geq 60\%$, and the elevation of green space is lower than that of roads, forming a natural catchment gradient of “road - green space” to ensure that road rainwater flows into green space sponge facilities by gravity.

4.2. Architectural Design: Building a "Sponge-Empowered" Green Building System

As the core element of residential areas, buildings need to integrate sponge functions from three dimensions: roof, facade, and ground floor space to realize the

coordination between buildings and rainwater management (Figure 2). The specific design schemes are as follows:

4.2.1. Green Roof Design

It adopts a ‘modular’ system (suitable for flat roofs with slopes $\leq 25^\circ$). The structure from bottom to top is as follows: the waterproof layer uses SBS modified asphalt waterproofing membrane with a thickness of $\geq 4\text{mm}$ superimposed with root-resistant waterproofing membrane with a thickness of $\geq 1.5\text{mm}$ to prevent root damage to the structure; the drainage layer uses plastic drainage boards with a thickness of $\geq 50\text{mm}$, covered with geotextile with a permeability coefficient of $\geq 1 \times 10^{-3} \text{ cm/s}$ to avoid blockage of drainage channels; the planting soil layer is “peat soil + perlite + vermiculite” (volume ratio 3:2:1) with a thickness of 150-200mm (150mm for light roofs and 200mm for roofs with a bearing capacity $\geq 2.0\text{kN/m}^2$), organic matter $\geq 3\%$, pH value 6.5-7.5; the vegetation layer selects drought-tolerant native plants such as Sedum lineare, with a height of 10-30cm and coverage rate $\geq 90\%$; the rainwater collection system is equipped with 100mm high water retaining ridges, and a 100mm diameter rainwater inlet (with a 5mm aperture filter screen) is set every 5-8m. Rainwater is connected to the underground reservoir through a 150mm diameter special pipeline. This design can retain 70%-80% of roof rainwater, reduce the roof temperature by 8-12°C, and reduce summer air conditioning energy consumption by 15%-20%.

4.2.2. Vertical Greening Design

It is suitable for the east-west facade of buildings (to reduce solar radiation) and the overhead column surface of the ground floor. It adopts “prefabricated planting troughs” with a width of 300-400mm and a depth of 250-300mm, fixed on embedded parts with a spacing of 1.5-2m on the building facade. The bottom of the planting trough is provided with drainage holes with a diameter of 20mm and a spacing of 100mm, and the holes are connected to 50mm diameter PVC drainage pipes to guide excess rainwater into the ground grassed swales, and the planting substrate is “leaf mold + garden soil + river sand” (volume ratio 2:2:1), and 50g/m² slow-release fertilizer is added to meet plant growth, and select vine plants such as Parthenocissus tricuspidata (needing to set a 200×200mm metal grid to guide climbing) or hanging plants such as Chlorophytum comosum (planting density $\geq 5 \text{ plants/m}^2$). This design can reduce the temperature of the building facade by 3-5°C, improve the landscape recognition of the building, and improve the microclimate of the residential area[9,10].

4.2.3. Ground Floor Overhead Space Design

For residential buildings with ≥ 6 floors, the ground floor is overhead by 3-4m, and the overhead space is designed as a “semi-open sponge landscape area”. The specific scheme is as follows: the ground pavement uses permeable concrete with a permeability coefficient of $\geq 2 \times 10^{-2} \text{ cm/s}$, a thickness of 150mm, and a 200mm thick graded crushed stone cushion is laid underneath, with permeable geotextile laid in the cushion; in terms of landscape facilities, set up small rain gardens with an area of 10-15m² and a depth of 0.3m, matched with leisure seats made of anti-corrosion wood and landscape sketches such as stone lanterns and scenery walls. A 0.3m high wooden platform is set around the rain garden to facilitate residents' activities; in the drainage system, a 300mm wide and 200mm deep intercepting ditch is set around the overhead space, and the intercepting ditch is connected to the ground grassed swale to ensure

that rainwater in the overhead space can be discharged quickly to avoid water accumulation.



Figure 2. Sponge-Empowered Green Building System.

4.3. Landscape Facilities: Constructing a “Whole-Area Coordinated” Sponge Landscape System

Landscape facilities are the core carriers for realizing rainwater “infiltration, retention, storage, purification, utilization, and drainage”. It is necessary to design standardized and implementable technical schemes around four core facilities: rain gardens, grassed swales, permeable pavements, and reservoirs (Figure 3) .

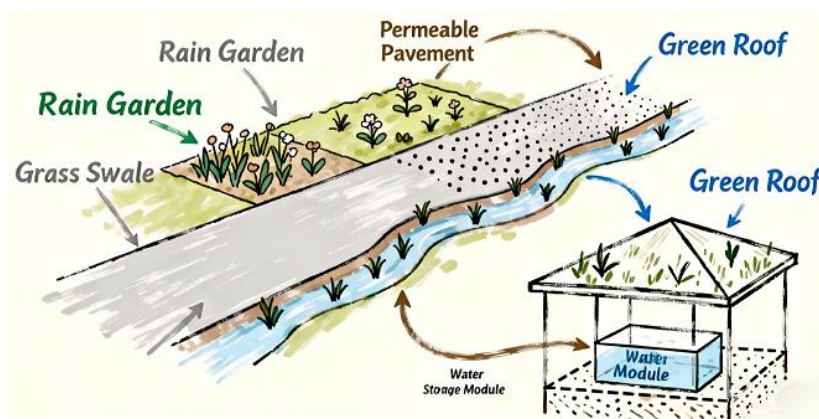


Figure 3. Schematic Diagram of the Collaborative System of Sponge Facilities in Residential Areas.

4.3.1. Rain Garden Design

Positioned as “ecological purification + landscape viewing”, it is divided into “simple type” (suitable for green spaces between residences) and “composite type” (suitable for central green spaces). The simple type has an area of 20-50m² and a depth of 0.3-0.4m, with a structure from bottom to top of 300mm thick graded crushed stone infiltration layer (particle size 20-50mm), 200mm thick mixed planting soil layer (peat soil: sand soil: leaf mold = 2:2:1), and 50mm thick mulch layer (bark or crushed stone). The water inlet is provided with a 1m wide crushed stone buffer zone (particle size 50-100mm), and native moisture-tolerant plants such as *Acorus calamus* are selected (density 3-5 plants/m²); the composite type has an area of 50-100m² and a depth of 0.4-0.6m. On the basis of the simple type, a sedimentation tank with a volume $\geq 5\text{m}^3$ (at the water inlet, paved with 50-100mm crushed stone) and a

100mm diameter perforated drainage pipe (hole spacing 100mm, buried at the bottom of the infiltration layer, connecting the sedimentation tank and the reservoir) are added. The plants adopt a “tree-shrub-herb” structure, with upper-layer plants such as *Salix babylonica* (plant spacing 3-5m), middle-layer plants such as *Hibiscus syriacus* (plant spacing 2-3m), and lower-layer moisture-tolerant herbs (Figure 4)[11] .

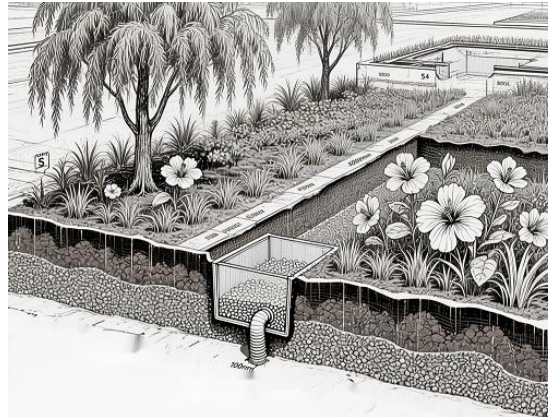


Figure 4. Composite Design Drawing of Rain Garden.

4.3.2. Grassed Swale Design

With dual functions of "water conduction + infiltration", it is divided into "ecological grassed swales" and "permeable grassed swales" (Figure 5). Ecological grassed swales are suitable for both sides of roads and edges of green spaces, with a width of 1.0-1.5m, a depth of 0.2-0.3m, and a slope of 2‰-3‰. The bottom of the swale is paved with 100mm thick mixed planting soil (garden soil: sand soil = 3:2), and trampling-resistant grass species such as *Cynodon dactylon* are planted (coverage rate $\geq 95\%$). A 100mm high and 300mm wide water retaining weir is set every 10-15m in the swale to extend the rainwater retention time and improve the infiltration effect; permeable grassed swales are suitable for areas with low soil infiltration coefficients. On the basis of ecological grassed swales, a 200mm thick graded crushed stone infiltration layer (particle size 10-30mm) is added at the bottom of the swale, with permeable geotextile laid in the layer. A 100mm diameter perforated drainage pipe is buried under the crushed stone layer to guide unpermeated rainwater into the reservoir, and the infiltration coefficient can be increased to more than $1 \times 10^{-2} \text{cm/s}$ [11].

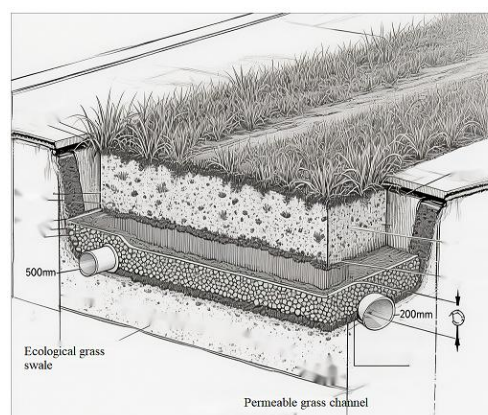


Figure 5. Design of Grassed Swales.

4.3.3. Permeable Pavement Design

It selects the type based on 'use case + carrying demand' that sidewalks/squares use 200×100×60mm permeable bricks with a compressive strength $\geq 30\text{MPa}$ and a permeability coefficient $\geq 3 \times 10^{-2} \text{ cm/s}$ (Figure 6). The base course is 150mm thick graded crushed stone (particle size 5-20mm) + 50mm thick medium-coarse sand leveling layer, and permeable geotextile is laid under the base course to prevent soil particle infiltration; parking lots use 300×300×80mm grass-planting bricks with a compressive strength $\geq 50\text{MPa}$ and a grass-planting hole rate $\geq 30\%$. The base course is 200mm thick C20 permeable concrete (permeability coefficient $\geq 2 \times 10^{-2} \text{ cm/s}$) + 100mm thick graded crushed stone, meeting the parking needs of small cars $\leq 2.5\text{t}$ and rainwater infiltration; road carriageways use permeable asphalt pavement, with a surface layer of 40mm thick AC-13 modified asphalt, a base course of 180mm thick ATB-25 asphalt-stabilized macadam, and a subbase course of 200mm thick cement-stabilized macadam (permeability coefficient $\geq 1 \times 10^{-3} \text{ cm/s}$). The road cross slope is 1.5%-2% to guide rainwater to converge to the grassed swales on both sides [12].

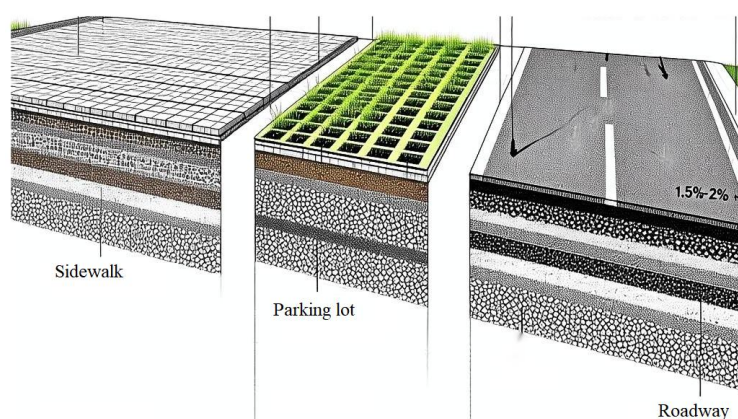


Figure 6. Schematic Diagram of Permeable Pavement Design.

4.3.4. Reservoir Design

It adopts an “underground concealed” design to avoid occupying the landscape space above ground that the volume is determined according to the residential rainwater utilization needs (greening irrigation, road cleaning) by “maximum daily water consumption $\times 3$ days” (Figure 7). For example, a residential area with 2500 households has a daily greening irrigation of about 50m^3 and road cleaning of about 20m^3 , so the reservoir volume $\geq 210\text{m}^3$; the structure adopts reinforced concrete, and the tank size is determined according to the site (such as $15\text{m} \times 7\text{m} \times 2\text{m}$). The tank wall thickness is 200mm, the bottom plate thickness is 250mm, the concrete strength is C30, and the impermeability grade is P6. The tank is divided into “sedimentation zone - filtration zone - storage zone”. The sedimentation zone is equipped with a 10mm aperture grille and an inclined tube sedimentation tank with a surface load of $1.0\text{m}^3/(\text{m}^2 \cdot \text{h})$. The filtration zone is filled with 0.5-1.0mm quartz sand (thickness 500mm). The storage zone is equipped with a submersible pump with a lift of 15m and a flow rate of $10\text{m}^3/\text{h}$; supporting automatic backwash filters (precision $100\mu\text{m}$), water level monitors, and 200mm diameter overflow pipes (500mm above the tank top, connected to the municipal rainwater pipe network) to ensure safe operation [13,14].

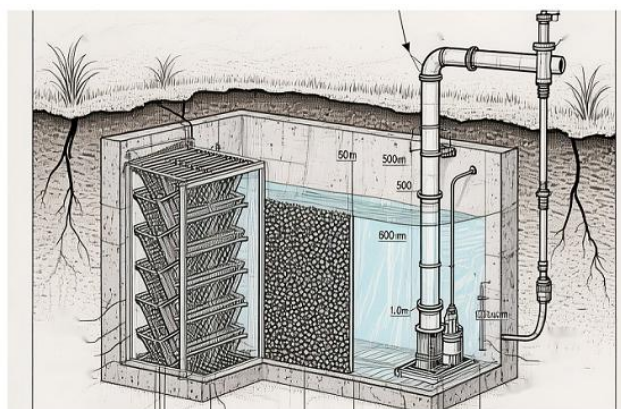


Figure 7. *Sectional View of Underground Reservoir.*

4.4. Operation and Maintenance Management: Establishing a “Long-Term Guarantee” Operation and Maintenance Mechanism

To ensure that sponge facilities continue to function effectively, it is necessary to establish an operation and maintenance mechanism from two aspects: responsibility division and technical standards. In terms of responsibility division, developers should provide complete drawings of sponge facilities and disclose them to property management companies upon completion; property management companies are responsible for daily inspections, checking whether facilities are blocked or damaged, and carrying out work such as fallen leaf cleaning, pore dredging, and water level monitoring; professional operation and maintenance units conduct professional maintenance every quarter, including plant pruning and replanting, water quality testing and cleaning, and facility performance testing [15,16]. In terms of technical standards, formulate special operation and maintenance procedures: rain gardens need to regularly clean up debris, replant plants, test the infiltration performance of planting soil, and replace it in a timely manner; permeable pavements need to regularly clean up dust and sediment, and flush pores to maintain infiltration performance; reservoirs need to regularly test water quality, clean up sludge, and carry out tank leakage testing and repair.

5. Case Analysis of the Integrated Design of Residential Landscape and Architecture Based on the Sponge City Concept

5.1. Project Overview

A public rental housing project in Shenzhen covers a total area of about 85,000 m², with a total construction area of 280,000 m². It has 12 residential buildings and a planned total of 2,500 households (Figure 8). The project deeply integrates the sponge city concept throughout the whole process, realizes the integrated design of landscape and architecture through various low-impact development measures, and finally achieves excellent rainwater management effects and ecological benefits.



Figure 8. General Layout Plan of the Public Rental Housing Project in Shenzhen.

5.2. Integrated Design Scheme of Landscape and Architecture

5.2.1. Site Planning and Design

The project takes “sponge priority” as the core principle, and scientifically arranges spatial elements such as buildings, roads, green spaces, and water bodies in combination with the natural terrain and hydrological conditions of the site. Multiple drainage zones are divided according to the terrain slope, and each zone is equipped with an independent rainwater management system to ensure on-site collection, infiltration, and utilization of rainwater. At the same time, some original natural green spaces and water bodies of the site are retained and incorporated into the sponge system after ecological restoration and transformation, further improving the rainwater regulation capacity and ecological quality of the residential area.

5.2.2. Architectural Design

The project deeply integrates sponge measures with the green building concept. The building roofs are built with about 12,000 m² of green roofs, accounting for more than 60% of the total roof area. It adopts a structure of “vegetation layer + planting soil layer + filter layer + drainage layer”, and selects drought-tolerant and barren-tolerant plants such as *Sedum lineare* and *Sedum sarmentosum*. Green roofs can not only retain and collect rainwater, reduce runoff, but also optimize the thermal insulation performance of buildings, reduce energy consumption, and add landscape highlights to the residential area. In addition, 5,000 m² of vertical greening is set on the building facades, planting vine plants such as *Parthenocissus tricuspidata* and *Hedera helix*, which not only beautify the building appearance but also reduce the wall temperature and improve the microclimate of the residential area.

5.2.3. Landscape Facility Design

The project constructs a multi-level sponge facility system, including rain gardens, permeable pavements, grassed swales, and reservoirs. Among them, the total area of rain gardens is 8,000 m², with 20 in total. It adopts a structure of “water inlet + water storage layer + planting soil layer + infiltration layer + water outlet”, planting moisture-tolerant plants such as *Phragmites australis* and *Acorus calamus*, which can collect and purify surrounding rainwater and reduce runoff pollution; the area of permeable pavements is 25,000 m², applied to sidewalks, parking lots, and squares, using permeable bricks and permeable concrete to accelerate rainwater infiltration and supplement groundwater; the total length of grassed swales is 3,000 m, arranged on

both sides of roads and edges of green spaces, planting *Cynodon dactylon* and *Zoysia japonica* to guide rainwater flow and extend retention time; an underground reservoir with a total volume of 500 m³ is set under the underground garage and landscape water body to collect rainwater for greening irrigation, road cleaning, and landscape water supplement, realizing the recycling of rainwater resources [17,18,19].

5.3. Implementation Effect Analysis

The project has achieved relatively remarkable implementation results. Based on monitoring data, it is indicated that when the rainfall intensity is approximately 20mm/h, the rainwater runoff coefficient of the residential area has decreased from approximately 0.7-0.8 observed in traditional residential areas to approximately 0.3-0.4, and the total runoff has decreased by more than 50% or so; the rainwater infiltration has increased by more than 30% approximately, effectively supplementing groundwater to a certain extent; the rainwater purification rate exceeds approximately 80%, and the water quality has been significantly improved. The ecological and social benefits are also relatively prominent. The green space rate of the residential area has increased from 30% of traditional ones to more than 40%, and the ecological quality has been significantly improved; a questionnaire survey shows that residents' satisfaction with the residential environment reaches more than 90%, and the quality of life has been greatly improved [20,21].

Comparison Item	Traditional Residential District	Sponge city Residential District
Rainwater Runoff Coefficient (Rainfall Intensity 20mm/h)	0.7-0.8	0.3-0.4
Change in Total Runoff Volume	No significant reduction (baseline state)	Reduced by more than 50%
Increase in Rainwater Infiltration Volume	No significant increase	Increased by more than 30%
Rainwater Purification Rate	Not clearly mentioned	Over 80% (water quality significantly improved)
Residential District Green Space Rate	30%	Over 40% (ecological quality significantly improved)
Residents' Satisfaction with Residential District Environment	Not clearly mentioned	Over 90% (quality of life greatly improved)

5.4. Discussion

The integrated design strategy proposed in this study has achieved good results in the public rental housing project in Shenzhen. The core ideas and methods are applicable to urban residential districts with subtropical monsoon climate and high population density, providing a practical paradigm for sponge city construction in similar residential districts. However, the research has limitations: only taking this public rental housing project as a case, the covered climate zones, topographic conditions and residential district types are single, and the applicability of the results in other climate zones and topographies needs to be verified; the evaluation indicators do not fully consider economic costs, and the quantitative analysis of the costs and benefits of sponge facilities is insufficient; conventional sponge technologies are mostly adopted, and the research on the integrated application of intelligent technologies is limited [22,23].

Future research can be carried out from four aspects: exploring differentiated integrated design schemes for different climate zones, topographic conditions and residential district types to improve universality; constructing a comprehensive evaluation system including costs and multiple benefits to quantify economic feasibility; strengthening the integration of intelligent technologies and sponge facilities, and building a management platform to improve operation and maintenance efficiency; conducting long-term follow-up monitoring of renovated residential districts to provide data support for strategy optimization.

6. Conclusions

Focusing on solving the core problems such as the functional separation of landscape and architecture in residential districts and insufficient rainwater management efficiency, this paper completes the theoretical exploration, strategy construction and empirical verification of the integrated design of residential district landscape and architecture based on the sponge city concept. The research is reflected in three aspects: First, it establishes a theoretical framework of integrated design featuring “conceptual coordination, spatial integration, and functional complementarity.” This framework clarifies the in-depth connections between the sponge city concept and residential design in terms of objectives, technologies, and benefits, breaking down the disciplinary barriers between architecture and landscape. Second, it proposes a four-dimensional collaborative design strategy encompassing “site planning, building ontology, landscape facilities, and operation and maintenance management.” Specific schemes—including the “three-step method” for site planning, “three-dimensional sponge empowerment” for buildings, and “full-area collaboration” for landscape facilities—provide standardized technical paths for design practice. Third, it develops a multi-dimensional evaluation system integrating “hydrological monitoring, ecological assessment, and resident feedback.” Combined with a case study of affordable housing in Shenzhen, the effectiveness of the design strategy is verified, making up for the shortcomings of a single evaluation perspective [24,25]. In the future, it is necessary to further expand the research scope, conduct studies on differentiated design for different climate zones, topographical conditions, and residential types, and strengthen the integrated application of intelligent monitoring technologies and sponge facilities. This will promote the transformation of residential sponge design from “pilot demonstration” to “standardization and normalization,” solidify the ecological foundation of residential units for urban sustainable development, and realize the harmonious coexistence between cities and nature.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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