Rainwater Recycling in the Design and Construction of Urban Landscape Engineering

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Abstract: With the increase in China's population, the amount of available freshwater resources is gradually decreasing, and the per capita water resource possession in China is far below the world average. Therefore, it is an inevitable choice to enhance water resource utilization efficiency through scientific methods. In this regard, this paper elaborates on specific measures for achieving rainwater recycling in the design and construction of urban landscape engineering, aiming to provide valuable references for relevant practitioners.

1. Introduction

Under the backdrop of urbanization, water scarcity has emerged as a prominent issue. Rainwater, as a vital renewable resource, has become a crucial measure to address the urban water crisis. In the design and construction of urban landscape engineering, the effectiveness of rainwater recycling directly influences the level of sponge city construction. Modern landscape engineering reasonably utilizes water resources through facilities such as rain gardens and water storage tank technologies, providing a stable water supply for gardens.

2. The Importance of Rainwater Recycling in the Design and Construction of Urban Landscape Engineering

Achieving water recycling in the design and construction of urban landscape engineering contributes to promoting sustainable urban development and improving ecological environmental degradation. Specifically, its importance is reflected in the following aspects:

2.1 Water Resource Utilization

During urbanization, the demand for water increases, which contradicts the scarcity of freshwater resources [1]. As a renewable resource, rainwater recycling can effectively supplement the shortage of urban water resources. In urban water use, landscape irrigation constitutes a significant part. By setting up facilities such as rain gardens to collect rainwater and scientifically purifying it for vegetation irrigation, the dependence on municipal water supplies can be reduced. According to relevant surveys, a well-established rainwater recycling system can meet more than half of the irrigation water demand in gardens, significantly alleviating urban water supply pressure.

2.2 Ecological and Environmental Protection

Traditional rainwater drainage modes are prone to causing water pollution and severe urban waterlogging issues. In rainwater recycling, facilities such as sunken green spaces and grass swales are set up to reduce surface runoff and decrease the frequency of urban waterlogging [2]. Meanwhile, during rainwater recycling, purification through plants and soil can reduce urban water pollution and effectively improve the urban ecological environment. For example, rain gardens can remove a large amount of suspended solids from rainwater and effectively purify nutrients such as nitrogen and phosphorus.

2.3 Economic and Social Value

Rainwater recycling can reduce the operational costs of urban landscape engineering and

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decrease drainage system maintenance expenses. It also enhances environmental awareness among urban residents and expands the influence of sponge city construction concepts.

2.4 Coping with Climate Change

Rainwater recycling optimizes urban rainwater utilization while considering ecological protection and water conservation, fundamentally enhancing urban resilience.

3. Pathways for Achieving Rainwater Recycling in Urban Landscape Engineering Design

3.1 Plant Configuration Design

In the rainwater recycling system of urban landscape engineering, plant configuration is a core element that plays a crucial role in connecting ecological functions and landscape effects. Reasonable plant configuration can not only purify rainwater but also enhance rainwater infiltration capacity and maintain the ecological stability of gardens [3]. When selecting plants, the principle of ecological adaptability should be followed, with priority given to native plants that have strong purification capabilities and are resistant to waterlogging and drought. Native plants are well-adapted to local soil and climatic conditions, reducing later maintenance costs and performing stably in rainwater recycling scenarios. For example, aquatic plants such as reeds can be selected for core areas like grass swales, using their developed root systems to adsorb pollutants in rainwater and intercept suspended solids. In green spaces around permeable pavements, drought-resistant plants such as Zoysia japonica can be chosen to effectively absorb water during periods of abundant rainfall and maintain ideal landscape effects during droughts, preventing plant death due to excessive water loss. In plant combinations, a multi-level community structure should be constructed to form a three-dimensional rainwater treatment system. Vertically, a plant combination mode of trees + shrubs + herbs can be used. Deciduous trees such as Sophora japonica can be selected for the upper layer, using their canopies to slow down the speed of rainwater falling and reduce surface erosion [4]. For the middle layer, moisture-resistant shrubs such as Hibiscus syriacus can be chosen to effectively intercept rainwater and filter out excess impurities. For the lower layer, ground cover plants can be used to cover surface gaps and enhance soil permeability. Horizontally, gradient configuration should be carried out according to the actual flow direction of rainwater, with waterlogging-resistant plants planted in areas where rainwater collects. In summary, in plant configuration design, plants should be scientifically selected, and plant structures should be reasonably combined to fully integrate natural ecological functions into the rainwater recycling system, enhancing the richness of garden landscape connotations while improving rainwater treatment effects.

3.2 Technology Integration Design

In the design of rainwater recycling in urban landscape engineering, technology integration design has transformed traditional modes and contributes to achieving system intelligence. By deeply integrating modern information technology, automation control technology, and renewable energy technology, precise rainwater recycling can be realized, actively allocating rainwater while enhancing the functionality and ecology of garden landscapes. Intelligent monitoring technology lays the foundation for precise management of the rainwater system. Sensors such as water quality monitoring sensors and rainfall sensors should be scientifically deployed in the design to construct a comprehensive and real-time data collection network. Rainfall sensors can be installed at high points in the garden to dynamically collect data on rainfall amounts and precipitation intensity parameters, providing references for optimizing and adjusting rainwater collection strategies. Liquid level sensors can be installed in rainwater storage tanks to monitor water level changes in real time, preventing empty tanks or water overflow. Water quality sensors can be installed at the inlets and outlets of water purification facilities to monitor indicators such as suspended solids, ensuring that the recycled rainwater meets irrigation requirements. The application of automation technology is conducive to enhancing the efficiency of rainwater recycling [5]. An intelligent monitoring system can be constructed in the design to link sensor data with executive equipment. When precipitation reaches a certain range, the system automatically opens diversion valves to guide rainwater into purification facilities. Predictive control based on meteorological data can also be implemented. For example, according to weather forecasts, the water level in storage tanks can be lowered in advance to reserve sufficient space for precipitation and prevent waterlogging. Additionally, the appropriate application of renewable energy technology provides necessary support for the rainwater system [6]. Specifically, lighting frames can be installed in garden landscapes, and solar photovoltaic panels can be added to convert solar energy into electricity, ensuring sufficient power supply for control systems, sensors, and other equipment and reducing dependence on municipal power sources. It should be noted that technology integration design is not a simple superposition of technologies but should be consistent with the layout of garden landscapes. For example, intelligent control cabinets can be hidden in rockeries, and sensor appearances can be designed to resemble stone shapes to prevent technical equipment from reducing the overall aesthetics of the garden.

4. Pathways for Achieving Rainwater Recycling in Urban Landscape Engineering Const ruction

4.1 Construction Preparation Work

Pre-construction preparations are essential guarantees for the implementation of the rainwater recycling system in urban landscape engineering, preventing the failure of rainwater recycling functions due to inadequate early preparations.

4.1.1 Technical Preparation Stage

The core of technical preparation is to verify the feasibility of the design. Technical teams should be organized to conduct construction drawing review work, focusing on analyzing and checking the details of key rainwater recycling facilities, clarifying the technical key points of each facility's construction, and understanding the connection logic between different construction techniques. For example, standards for the base compaction degree of permeable pavements should be formulated in advance. Targeted solutions should be developed for potential on-site adaptation issues in the design. A comprehensive construction plan should be compiled to achieve refined management of the rainwater recycling process, clarifying quality control points for each construction procedure, such as the installation steps of rainwater purification modules and the specific sequence of laying permeable materials. Technical disclosures should also be carried out simultaneously to ensure that construction personnel master the application methods of rainwater recycling facilities.

4.1.2 On-Site Preparation Stage

On-site preparation aims to achieve precise adaptation to the construction environment. First, a detailed survey of the construction site should be conducted, focusing on recording soil permeability, the distribution of underground pipelines, and the operational status of drainage systems. Soil sampling and testing should be carried out to clarify permeability parameters. If the soil permeability is poor, a replacement and improvement plan should be formulated in advance. The specific locations of underground pipelines should be clearly marked to prevent construction damage from hindering the effective connection of rainwater pipelines. Subsequently, site cleaning should be carried out to thoroughly remove obstacles within the construction range. Micro-topography should be appropriately adjusted according to the actual flow direction of rainwater to create favorable conditions for the construction of permeable pavements and other facilities [7].

4.1.3 Material and Equipment Preparation Stage

Strict quality control should be implemented for materials. The quality of rainwater recycling-specific materials should be carefully checked, and key indicators such as anti-seepage performance and compressive strength should be sampled and tested to ensure compliance with design standards. Rainwater pumps and other intelligent equipment should be debugged in advance to test the stability of their data, and sufficient spare parts for equipment should be reserved.

4.2 Construction of Permeable Pavement Systems

The construction quality of permeable pavement systems in garden landscape engineering directly affects the efficiency of rainwater infiltration. In this construction link, strict control should be exercised over base treatment, surface layer paving, and joint treatment to enhance the stable permeability of the pavement while meeting bearing requirements. In base construction, a solid foundation for permeability should be laid. The roadbed should be rolled and treated using heavy rollers for layered compaction, ensuring a compaction degree of approximately 94% to prevent later settlement from damaging the permeable structure. Subsequently, a crushed stone base should be laid, with a particle size of about 30 mm and a thickness of about 17 cm. During specific laying, leveling should be carried out layer by layer, with a compaction degree of each layer greater than or equal to 90%. If the soil permeability is insufficient, a permeable geotextile should be added between the base and the roadbed to prevent soil particles from blocking the gaps in the crushed stones and ensure the smooth infiltration of rainwater into the ground. Surface layer paving should take into account both permeability and durability. Before the construction of the permeable brick surface layer, a 4 cm thick dry hard cement mortar with a ratio of 1:3 should be laid. When laying permeable bricks, they should be arranged strictly according to the design patterns, ensuring a 4 mm gap between bricks. Special permeable joint fillers should be used for filling treatment to prevent mud and sand from being carried away when rainwater permeates through the gaps. During the construction of the permeable concrete surface layer, the rationality of aggregate gradation and cement dosage should be ensured, with the cement amount not exceeding 300 kg/m^3. A plate vibrator should be used for light vibration and compaction during pouring. Additionally, quality control should be strengthened during construction. After the completion of base and surface layer construction, the permeability coefficient should be sampled and tested to ensure that the permeability coefficient of the permeable brick pavement system is within a reasonable range.

4.3 Construction of Sunken Green Spaces and Grass Swales

Sunken green spaces and grass swales are important components of the rainwater recycling system in gardens. Their construction utilizes methods such as intercepting pollutants to retain rainwater and enhance the quality of resource utilization. During construction, the focus should be on planting plants and improving soil to effectively coordinate ecological functions and landscape effects. In the construction of sunken green spaces, the terrain height difference should be controlled within a reasonable range. The site should be excavated according to the actual design elevation, and the base should be compacted and treated to ensure a compaction degree of about 88%, preventing later settlement from affecting the function of water collection. When improving the soil, an appropriate amount of river sand and rotten leaves should be added to reduce the clay content of the soil and improve the soil permeability coefficient. If the original soil permeability is poor, a certain thickness of crushed stone blind ditches should be laid, and the blind ditches should be filled with crushed stones and wrapped with permeable geotextiles to enhance the rainwater infiltration capacity and avoid water accumulation in the green spaces. In the construction of grass swales, attention should be paid to their functionality, and the trench should be excavated according to the designed cross-section. Generally, a trapezoidal cross-section is used, with an upper width of 1–2 m and a lower width of 0.5–1 m. A 10 cm thick layer of planting soil should be laid at the bottom of the trench, and an appropriate amount of perlite should be mixed in to enhance its air permeability. To achieve ideal purification effects, a crushed stone filtration zone can be set up at the bottom of the trench, filled with crushed stone mixtures, etc., to effectively adsorb nitrogen and phosphorus pollutants in rainwater.

4.4 Construction of Rainwater Storage and Purification Facilities

Rainwater storage and purification facilities play important roles in the rainwater recycling system, undertaking functions such as pollutant removal and rainwater storage. During actual construction, the anti-seepage performance of storage facilities and the functionality of purification facilities need to be controlled module by module to ensure the reasonable utilization of rainwater. In the construction of rainwater storage facilities, the focus should be on ensuring anti-seepage and capacity. For example, in the construction of underground reinforced concrete water storage tanks, the foundation pit should be excavated first, and slope protection with steel sheet piles should be carried out when the depth exceeds 3 m. An appropriate thickness of cushion should be laid at the bottom of the foundation pit. When the strength meets relevant standards, steel bars should be bound, and the spacing and protective layer thickness of the steel bars should be set strictly according to design requirements to avoid excessive steel bar spacing affecting the overall structural bearing capacity. Steel forms should be used for formwork installation, and sealing adhesive strips should be pasted at the joints to prevent concrete pouring from causing grout leakage. In the construction of rainwater purification facilities, attention should be paid to the layered purification effect. For example, in the construction of artificial wetland purification, an anti-seepage membrane should be laid first, ensuring that the width between membranes is greater than or equal to 10 cm. Double-weld technology should be applied, and pneumatic testing should be carried out after welding to ensure that the anti-seepage performance is within the specified range. Subsequently, layers of crushed stone, substrate, and planting layers should be laid. Finally, aquatic plants such as Acorus calamus should be selected, ensuring that their root systems penetrate deep into the substrate layer.

5. Conclusion

In conclusion, in urban landscape engineering, the design and construction of rainwater recycling organically integrate ecological concepts with engineering practices. This systematic project injects vitality into garden landscapes, contributing to strengthening sponge city construction and optimizing urban water cycles. In the future, continuous exploration should be carried out to find the balance between technological innovation and cost, making rainwater recycling a representative feature of urban gardens.

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