Stormwater Management for Religious Gardens in Hangzhou Study on the Current Situation of Facility Application and Optimisation Strategies

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Abstract. Religious gardens are one of the essential types of gardens. The geographic location divides differences into three categories: urban, mountain, forest, and comprehensive. The guide space and transition space, and other dispersed spaces are densely populated, and the terrain is flat and not easy to drain, so they are facing a big challenge of rainwater management. The article examines the current status of the application of stormwater management facilities in Hangzhou religious gardens through the field research method. It discusses the distribution and application of municipal stormwater and low-impact development facilities. More research is needed on the application of stormwater facilities in religious gardens, and this study will provide inspiration and reference for the application and optimization of stormwater facilities in religious gardens in the context of sponge cities.

Keywords: religious gardens; stormwater management; municipal stormwater facilities; low impact development stormwater facilities; Hangzhou

1 Introduction

Driven by sustainability principles and low-impact development, the creation of sponge cities centered on "natural accumulation, natural purification, and infiltration," has become imperative [1-2]. However, areas such as guiding, garden, and transition spaces, characterized by flat terrain and minimal elevation changes, often face challenges in effectively managing rainwater and mitigating flood risks [3-5].

Research on religious gardens encompasses both horizontal and vertical dimensions [6]. Horizontally, it examines their material and cultural attributes; the material aspects cover location, type, spatial structure, architectural layout, plant arrangement, and gardening techniques, while cultural attributes encompass Buddhist culture, humanistic ideas, and literary creation within monastic environments [7-8]. Vertically, the research focuses on historical evolutions and related topics. Given the need for an enhanced understanding of the environmental functions and the rain and flood management capabilities of religious gardens, this study uses Hangzhou's religious gardens as a case study to conduct a systematic review of their rainwater facility usage, identify existing

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challenges, and develop optimization strategies. This research aims to improve rainwater management in religious gardens and serve as a reference for future enhancements.

2 Overview of the Study Area and Research Methodology

2.1 Overview of the Study Area

Hangzhou, positioned in the Jiangnan region of China between latitudes 29°11′N and 30°33′N and longitudes 118°21′E and 120°30′E, experiences a hot and humid subtropical monsoon climate. Characterized by a dense longitudinal river network and heavy rainfall, the city is particularly susceptible to flooding during the rainy season. From 1981 to 2010, the average annual rainfall in Hangzhou was 1,439.7 mm, contributing to frequent urban flooding and soil erosion issues. Known as the "Southeast Buddhist Kingdom," Hangzhou hosts many historical religious sites. These sites are popular tourist destinations and vital for studying religious gardens due to their continuous influx of visitors.

2.2 Research Methodology

This study analyzes eight religious gardens in Hangzhou, selected based on type, location, completion, and scale. Conducted from October 2022 to May 2024, the research focuses on the efficacy of rainwater management systems during adverse weather, categorizing the gardens into urban, mountainous, and comprehensive types. Employing field observations and photographic documentation, the study assesses types, materials, quantities, and functions of stormwater facilities, along with their aesthetic integration, to provide a detailed analytical overview (Table 1).

Table 1. Overview of some religious gardens in Hangzhou (source of the table: author's drawing).

Site Name	Location	Type
Xiangji emple	North Gate of Hangzhou	the Urban type
Fenghuang Temple	Imperial Street of the Southern Song Dynasty	the Urban type
Lingyin Temple	Between Feilai Peak Peak	the mountain and forest-type
Huanglong Cave	At the foot of Qixialing Ridge	the mountain and forest-type
Hupao Temple	Below Daci Mountain	the mountain and forest-type
BaopuTaoist Temple	Gelling Hillside	the mountain and forest-type
Agate Temple	Foothills of Agate Mountain	the Comprehensive type
Jingci Temple	Below Huirifeng of Nanping	the Comprehensive type

3 Findings and Analyses

3.1 Analysis of Different Types of Stormwater Facility Applications

Municipal Stormwater Facilities.

Hangzhou's religious gardens' main municipal stormwater facilities include rainwater inlets, drainage ditches, and rainfall pipes. Rainwater inlets are the most common type, with a total of 83 applications, and the primary forms are pavement inlets, rain grates, and drainage outlets. Drainage ditches, with 18 applications, are mainly artificial ditches. Rainfall pipe is the least applied, only 16 times. Rainwater inlets on both sides of religious garden roads are mainly responsible for collecting surface rainwater runoff, and due to differences in material and form, stone rainwater inlets usually have a lower rainwater transfer rate than metal rainwater grates. Drainage swales are generally located at the edges of green spaces in gardens and act as the main stormwater conveyance facility for road surfaces, with faster runoff transfer rates. For flat-roofed buildings in gardens, roof rainwater is efficiently discharged into the stormwater system through rainfall pipes. However, while rain chains add aesthetics, their capacity to transmit rainwater is limited and may need to be improved to cope, especially during flooding.

Low-Impact Development of Stormwater Facilities.

In Hangzhou, six types of low-impact development (LID) facilities are implemented across religious gardens, ranked by frequency of use: permeable pavement (23 times), sunken green spaces (22 times), water storage bodies (19 times), elevated flowerbeds (10 times), rain gardens (9 times), and ecological tree ponds (2 times). Permeable pavement, the most prevalent, incorporates materials such as pebbles, messy stone, and embedded grass. Sunken green spaces and water storage bodies, which include both aboveground and underground cisterns, are also extensively used. The deployment of these LID facilities significantly contributes to the ecological sustainability and aesthetic enhancement of the gardens.

Comprehensive Analysis.

Frequency is how often a species appears in the surveyed area, and Frequency (Frequency) indicates the uniformity of the appearance of various rainwater facilities in religious gardens. Based on F (Frequency) = the number of religious gardens in which this type of rainwater facility occurs / the total number of religious gardens surveyed × 100%, the frequency of application of nine rainwater facilities in eight religious gardens in HCM City was obtained. The application frequency scale is low between 0% and 40%, average between 41% and 60%, high between 61% and 80%, and high between 81% and 100% (Table 2).

According to the analysis table of the application frequency of rainwater facilities in Hangzhou religious gardens, it can be seen that there are 5 types of rainwater facilities with an application frequency of $80 < F \leq 100$, accounting for 56% of the total number of rainwater facility types. The number of times each type appeared in the 8 religious gardens was 83 times, 18 times, 22 times, 22 times, and 19 times. Among them, the

application frequency of Rainwater inlets was 100%, which appeared in all 8 religious gardens. There are 2 types of rainwater facilities with application frequency of $60 < F \leq 80$, accounting for 22% of the total; 1 type of rainwater facility with application frequency of $40 < F \leq 60$, accounting for 11% of the total; and 1 type of rainwater facility with application frequency of $0 < F \leq 40$, accounting for 11% of the total. Table 2 shows that in the eight representative religious gardens selected, the stormwater outfalls and drainage ditches with higher application frequency are municipal stormwater facilities. The application of low-impact development facilities is relatively lacking, and the overall application variety is not rich enough. Nowadays, the more common low-impact development facilities, such as grass-planted ditches, infiltration channels, rainwater ponds, and infiltration ponds, etc., are not widely used in religious gardens.

Table 2. Analysis of the frequency of application of rainwater facilities in some religious gardens in Hangzhou (Table source: authors' drawing).

Frequency of application (100 percent)	Name of facility	Type of facility
$80 < F \leq 100$	Rainwater inlet	Municipal stormwater facilities
	Drainage ditch	Municipal stormwater facilities
	Sunken green space	Low-impact development facilities
	Permeable pavement	Low-impact development facilities
	Detention Basin	Low-impact development facilities
$60 < F \leq 80$	Elevated flowerbed	Low-impact development facilities
	Downspout	Municipal stormwater facilities
$40 < F \leq 60$	Rain garden	Low-impact development facilities
$0 < F \leq 40$	Ecological Tree Pond	Low-impact development facilities

3.2 Comparison of the Application of Stormwater Facilities in Different Types of Religious Gardens

Analysis of Stormwater Facilities in Urban-Type Religious Gardens.

Urban-type religious gardens are located primarily in urban areas and their suburbs, and usually stand alone, lacking external landscaping. Their internal gardens are mostly man-made, gently sloping and rely mainly on municipal stormwater management systems for drainage. These gardens have a limited range of stormwater facilities, with only seven, which is relatively homogenous compared to other types of religious gardens.

There are three municipal stormwater facilities in urban-type religious gardens, mainly rainfall pipes, Rainwater inlets, and drainage ditches. Rainwater inlets appear

the most often, 43 times, mostly set up in the gentle catchment space, and are responsible for infiltrating rainwater runoff from hard-paved surfaces. The application effect is good. Rainfall pipes have the second highest number of occurrences, totaling 11, and are mainly responsible for transmitting rainwater runoff from roofs, with better aesthetic effects; drainage ditches have the lowest number of occurrences, totaling 4. Low-impact development facilities were 4 in total, with hollow green spaces occurring 3 times, permeable paving 2 times, raised flower beds 1 time, and retention of water bodies 1 time. In urban religious gardens, municipal stormwater facilities were used 58 times, accounting for 89 percent of the total, and low-impact development facilities were used 7 times, accounting for 11 percent. The data show that urban religious gardens in Hangzhou mainly use municipal rainwater facilities for rainwater management. Although the aesthetics of low-impact development facilities are higher than that of municipal rainwater facilities, the infiltration rate is lower than that of municipal rainwater facilities, so the application frequency is lower.

Analysis of Stormwater Facilities in the Mountain and Forest-Type Religious Gardens.

Mountain forest-type religious gardens are usually in natural mountainous areas with beautiful scenery. Due to its geographical location, the mountain forest-type religious garden mainly utilizes the difference in terrain elevation and natural ecological environment for rainwater management, with nine types of rainwater facilities, which is higher than the other two types of religious gardens.

In mountain and forest-type religious gardens, three types of municipal stormwater facilities are utilized: Rainwater inlets (24 times), drainage ditches (11 times), and rainfall pipes (5 times), with Rainwater inlets being the most prevalent. These inlets and ditches are effectively arranged to enhance rainwater infiltration on garden roads. Conversely, there are six types of low-impact development (LID) facilities, with water storage leading at 15 applications, followed by permeable paving (12 times), sunken green spaces (11 times), raised flower beds (6 times), ecological tree ponds (2 times), and rain gardens (1 time). LID facilities constitute 60% (58 times) of total implementations, surpassing the 40% (39 times) contributed by municipal facilities. LID facilities not only exceed in number but also offer superior aesthetic and functional benefits by reducing surface runoff through effective early stormwater management, which includes interception, infiltration, and temporary storage, thereby enhancing the environmental integration of stormwater management strategies.

Analysis of Stormwater Facilities in the Comprehensive Type Religious Gardens.

Comprehensive religious gardens are usually located in suburbs or towns with beautiful scenery and convenient transport. The overall environment combines natural landscapes with artificial landscaping. The number of rainwater facilities in comprehensive religious gardens is 7, which is lower than that of mountain and forest religious gardens.

In Comprehensive religious gardens, there are two types of municipal stormwater facilities: Rainwater inlets（16 times）, and drainage ditches（3times）. Rainwater

inlets, primarily positioned along road sides, effectively facilitate the infiltration of intercepted runoff; however, the placement of maintenance hole covers over permeable paving occasionally disrupts the aesthetics of pebble roads. Among low-impact development (LID) facilities, permeable paving is most common, appearing nine times, followed by sunken green spaces (8 times), raised flower beds and water storage bodies (3 times), and rain gardens (once). The application frequency of LID facilities in these gardens is 59% (24 times), compared to 41% for municipal facilities (19 times). Although both facility types show comparable effectiveness in application, the integration of municipal stormwater facilities can sometimes compromise the aesthetic coherence of LID facilities.

3.3 Comprehensive Analysis

Rainwater facility utilization varies across different types of religious gardens, with Huanglong Cave and Lingyin Temple showing the highest abundance, while Fenghuang Temple has the least. Mountain forest-type religious gardens have the most diverse and effective use of low-impact development facilities, which contribute to superior landscape effects. In contrast, urban religious gardens predominantly rely on municipal stormwater facilities with limited use of low-impact development types. Comprehensive religious gardens maintain a more balanced approach, utilizing both municipal and low-impact development facilities equally (see Fig. 1).

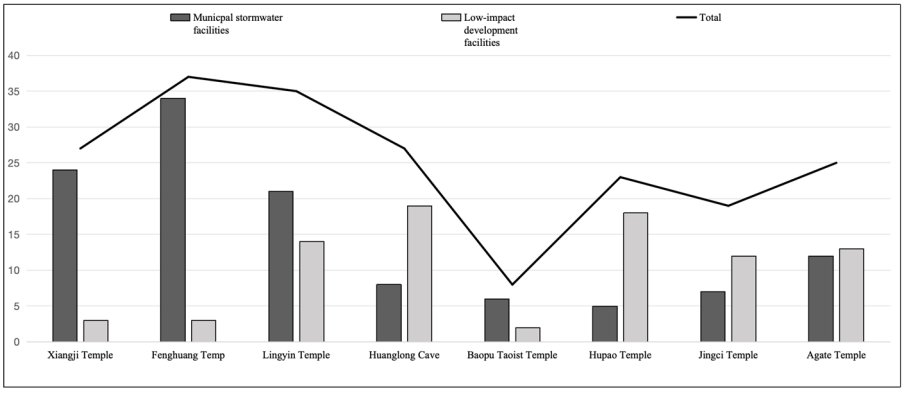

Fig. 1. Number of rainwater facilities applied in different religious gardens in Hangzhou (Photo credit: Author's drawing).

4 Discussion and Recommendations

4.1 Analysis of the Problem

Some Stormwater Facilities are in a Dilapidated Form and Functionally Impaired.

In the study of religious gardens, the primary failures of rainwater facilities are observed in transmission systems, notably at Jingci Temple and Lingyin Temple, where

rainwater inlets and drainage ditches are frequently clogged by leaves and debris. Without timely cleaning, these blockages impair rainwater collection and discharge, preventing the facilities from functioning effectively. This stagnation leads to waterlogging, which can cause soil erosion, vegetation damage, and degrade the overall landscape quality. Proper management and maintenance are essential to preserve the aesthetic integrity of the environment.

Lack of Preservation of Historical Authenticity of Some Stormwater Facilities.

The intense Zen atmosphere is a unique feature of religious gardens. Still, in recent years, the relevant departments in repairing some municipal stormwater facilities to achieve "rapid discharge," ignore the aesthetic degree, focusing only on its functional value. Part of the religious garden in the construction process has yet to deal with the relationship between municipal and low-impact development facilities, such as in the classical pavement directly above the superposition of paving the modern municipal maintenance hole cover. Also, ancient and contemporary visual experiences seriously affect the overall landscape. Excessive and disorderly repairs will lead to a severe loss of the historical flavor and appearance of religious gardens, which is unfavorable to the protection and development of religious gardens.

Single Isolated System of Some Stormwater Management Facilities.

Rainwater management in religious gardens often lacks integration, particularly in executing the "seepage, stagnation, storage, purification, use, discharge" technology line. This disconnection emphasizes storage disproportionately while neglecting the interconnected processes of rainwater transmission and reuse. Religious gardens typically differ from other Jiangnan gardens in their water systems, which are dispersed across multiple points, limiting the overall ecological benefits of rainwater management. Additionally, many storage ponds in these gardens serve primarily as landscape features without forming a cohesive system with surrounding rainwater facilities, thereby restricting effective control over local runoff. This fragmentation can lead to water stagnation and insufficient rainwater management, posing inconveniences to visitors and users.

4.2 Optimisation Recommendations

Maintenance of Existing Stormwater Facilities and Addition of New Facilities.

To ensure the effectiveness of stormwater management in religious gardens, it is essential to regularly clear conveyance-type facilities of any obstructions at inlets to avoid drainage clogging. Bioretention facilities require periodic weeding and mowing to preserve healthy vegetation. Given the predominance of hard paving, which restricts rainwater infiltration, it is advisable to augment permeable paving. Utilizing highly porous materials and adopting traditional garden paving methods such as diverse and patchwork designs can enhance permeability. This approach facilitates rainwater infiltration and plant water uptake and allows for the integration of grass-inserted permeable paving.Low-impact development (LID) facilities in religious gardens, including

grassed swales, infiltration pipes/channels, and vegetated buffer strips, are employed in a limited capacity and comprise six types. The expansion of bioretention facilities is recommended to boost landscape diversity and functionality.

Integration of Facility Construction and Rainwater Utilization to Enhance the Zen-like Atmosphere.

The "First Spring in the World" at Hupang Temple, the "Thousand Dragons Spitting Water" at the Forbidden City, and the Bathing Buddha Pool at Jingci Temple demonstrate the effective integration of rainwater harvesting and landscape elements, which is a crucial strategy for enhancing the Zen flavor of religious gardens. These water bodies not only form the focal point of the landscape but also assume the function of rainwater saving. By integrating rainwater landscape vignettes, the gardens not only enhance aesthetics but also deepen the cultural level of Zen while enhancing the interest and efficiency of rainwater management. Rainwater facilities can be configured in conjunction with the existing water bodies in the garden to maximize the use of existing water resources and reduce the amount of engineering work while simultaneously fulfilling the function of rainwater management.

Coordinate and Improve the Rainwater Management Model System to Enhance Response Capacity.

Planning and design should be based on the original rainwater management system in later managing and repairing religious gardens. Suppose only municipal facilities are used for the direct infiltration of rainwater. In that case, it will reduce the creation and dispersion of a series of scenarios, such as "flying springs on the eaves" and "rain hitting bananas" in the gardening method of classical Chinese gardens to a certain extent, which will significantly reduce the philosophical experience of landscape and water in the religious gardens. The experience of landscape philosophy in religious gardens has decreased considerably. Therefore, it is necessary to improve the broken part's function and supplement the Lack of transmission links to form a more complete water cycle system in the garden.

5 Conclusion

The rational planning of stormwater facilities in religious gardens positively impacts urban stormwater management. According to the different environments, there are differences in the rainwater management ability of various types of religious gardens, and in terms of the richness of rainwater facilities, it is shown as mountain and forest religious gardens＞comprehensive religious gardens＞urban comprehensive gardens; in terms of the type of application of rainwater facilities, mountain, and forest religious gardens make use of low-impact development facilities more often, urban religious gardens make use of municipal facilities more often, and comprehensive religious gardens are more balanced in terms of the application of rainwater facilities. They are more

balanced, with no apparent bias. The vast majority of religious gardens rely on the establishment of water diversion, water storage, water retention, and drainage systems to manage rainwater on the internal environment of roads, green spaces, water features, buildings, and other diverse subsurfaces to achieve the purpose of reducing surface runoff, effective use of water resources and improving the ecological environment.

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