Landscape design of rainwater reuse based on ecological natural environment: Hangzhou as an example

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Abstract
Rainwater reuse is an important technical measure in the steps of rainwater reuse in landscape construction, and it has important research and application value. China has a large land area, and the climatic conditions in different regions are different. Landscape design based on rainwater reuse must also be adapted to local conditions. This article analyzes and summarizes the relevant theories and case studies of ecological and natural environment management at home and abroad and, based on the construction research conclusions of the landscape design based on rainwater reuse in Hangzhou, draws the foreign ecological and natural environment construction system, which not only emphasizes through engineering and non-engineering measures and other ways to deal with rain and flood, and attach great importance to public participation; public participation in ecological and natural environment management practices can not only enhance their own awareness of ecological and natural environment management, but also promote the operation of the entire system and establish a virtuous cycle mechanism. Based on this, this article further explores the organic combination of rainwater reuse management and landscape design, focusing on the combination of residential rainwater management and landscape elements such as topography, architecture, water sources, vegetation, and sustainability maintenance and education demonstration issues. Finally, this article takes a community in Hangzhou as an example, through the practice of optimizing the combination of rainwater management and environmental landscape; it provides a specific plan for the organic combination of rainwater management and environmental landscape in residential areas. Residential districts are an important part of the urban human settlement environment. This research not only provides suggestions for solving the rainwater problem in residential areas, but also provides new ideas for alleviating urban waterlogging problems. This article aims to promote its vigorous development in practice through the study of rainwater reuse in landscape design and apply the results to the natural environment.

Keywords Ecological natural environment · Rainwater reuse · Landscape design · Hangzhou city

Introduction
The urbanization process has changed the underlying surface structure of the original land. Rainwater falls on the ground and cannot naturally penetrate, causing a large amount of rainwater to be collected inside the city, resulting in rainwater problems of varying degrees (Alam et al. 2006). In order to alleviate urban water environment problems, the state has implemented and promoted the construction of landscape rainwater reuse, which is also an important technical step in the construction of sponge cities (Mei et al. 2019). There are many studies on rainwater reuse at home and abroad. In order to solve the limitations and disadvantages of traditional rainwater management, China strongly supports the construction of rainwater reuse landscape design (Melgani and Bruzzone 2004). The rainwater recycling landscape design emphasizes the use of low-impact technology development systems to create a safe water environment (Niu et al. 2020). Landscape rainwater reuse is not to overthrow the city’s original rainwater management system, but to combine the city’s existing drainage infrastructure and facilities (Pan et al. 2017). Use gray and green
infrastructure under zero pollution to achieve rainwater management purposes. As an important technical step in the low-impact development system, rainwater landscape design has the characteristics of low ecological impact on the environment, reducing construction costs, and reducing the difficulty of construction implementation (Paolotti et al. 2018). It has strong adaptability to the impact of natural landscape, so it can provide strong support for rainwater reuse and landscape construction. In recent years, Z Province has continuously promoted the rainwater reuse landscape construction policy and has guided and supported the development of related work in the province through the introduction of a series of related documents (Pei et al. 2020). In 2018, Z Province launched the “Approval Document for the Implementation of the Provincial People’s Government of Z Province on Promoting the Construction of Rainwater Reuse Landscapes in the Province,” which aims to optimize the construction of urban green parks and use space, rain gardens, underwater green spaces, and permeable spaces according to local conditions (Pradhan et al. 2020); use new measures to manage site rainwater; clean up rainwater runoff; and rationally use rainwater resources (Roy et al. 2020). Aiming at this point, this article first conducts a more in-depth study on the concept of low-impact development and the basic theory of landscape design for rainwater reuse. Based on landscape design, it analyzes and summarizes excellent cases at home and abroad (Samaniego et al. 2008). It also provides systematic guidance based on the landscape design and construction theory of rainwater reuse. Secondly, Hangzhou is selected as the research location to assess the ecological natural environment and rainwater reuse status in Hangzhou city, and conduct field investigations on rainwater reuse in Hangzhou city, conduct investigations based on relevant measures, and provide feasibility references for future research (Sekandari et al. 2020). When focusing on the rainwater utilization and landscape design and construction in Hangzhou, based on the landscape design of rainwater reuse, implement the theoretical system suitable for Hangzhou landscape design and construction and give priority to the overall landscape design and construction process to propose operation and maintenance recommendations. Finally, on the above, on the basis of the research, using Hangzhou Water Park as an example, under the guidance of established landscape design and construction strategies, a detailed analysis of the site status, drainage process, and rainwater runoff process is carried out, and on this basis, the rainwater management of the park is carried out (Sellami et al. 2019). Evaluation coefficient analysis proposes a transformation method for rainwater reuse in parks where rainwater is easy to gather, and combines relevant technical measures with low-impact development to improve the efficiency of rainwater control (Shao and Lan 2019). In the process of case experiment, the feasibility of landscape design and construction strategy based on rainwater reuse was verified, and concrete experience was provided for rainwater landscape design and construction in Hangzhou (Shao et al. 2018).

Materials and methods

Sources of information

Hangzhou is a mountainous city. The height of the mountains is usually less than 500 m, and the topography shows a downward trend from west to east. The terrain of the city is flat, mostly concentrated in the area of the Q River Estuary, the overall terrain is low, and the elevation is generally 3–10 m. Restricted by the natural topography, Hangzhou’s urban development is mainly concentrated in the eastern plains and is networked, with obvious advantages in water conservancy. The Q River and D Stream are the main rivers of the city and are known as “seven mountains, one water, and two fields” (Fig. 1).

Because Hangzhou’s most subdivided buildings and dense population are in the old city, and most of the old city is in the lower plain of Hangzhou, it is greatly affected by heavy rain and storms. If heavy rain or prolonged rain occurs in the city, waterlogging disasters are prone to occur. If the time and distance from the stagnant point to the drainage network can be increased, the problem of stagnant water can be solved. One approach is to establish low-impact measures between the source, medium, and terminal channels to minimize the concentration of runoff and reduce the length of runoff delay, thereby reducing the pressure on the municipal drainage network.

Calculation of landscape area for rainwater reuse

Make sure that the garden area Y is related to rainfall. However, the Hangzhou area has a monsoon climate, and rainfall is concentrated and extremely uneven for a period of time. If the maximum amount of precipitation is used to capture the surface area, the utilization efficiency will be low, the construction cost will be high, and the efficiency will be uneconomical. Even if the calculation result of the complete water balance method is more accurate, the calculation process is quite difficult and not suitable for daily use. Therefore, a ratio estimation method based on the obtained area can be used. Even if the calculation result is not very accurate, the advantage of this method is that it can simplify the calculation process, save the construction cost of Y Garden, and achieve a balance between cost and benefit. The formula is as follows:
Determine the area of the garden covered by rain:

\[ S_H = S_W \times \varphi_W + S_D + S_C \times \varphi_C \quad (1) \]

The total runoff \( Q \) is as follows:

\[ Q = S_h \times h \quad (2) \]

24-h water seepage depth \( h_0 \):

\[ h_0 = 24 \times r \times 3600 \quad (3) \]

The surface area of the rain garden is:

\[ S_h = \frac{Q}{h_0} \quad (4) \]

From formulas (2)–(4), we can get:

\[ S_h = 1.1574 \times 10^{-5} (S_W \times \varphi_W + S_D + S_C \times \varphi_C) \times h \times r \quad (5) \]

In addition, the actual area of garden \( Y \) can be estimated based on 5–10% of the undisturbed area of the catchment area.

Results

Analysis of climate, rainfall, and hydrological characteristics of Hangzhou

Hangzhou belongs to the subtropical monsoon climate zone. According to the statistics of monthly and annual average temperatures in the Hangzhou Statistical Yearbook for the past 10 years, the average temperature in the urban area of Hangzhou in the past 10 years is about 17.7 °C. Hangzhou spring can be divided into March to April. The average temperature is between 11.5 and 17.3 °C, and the climate is hot and humid; the summer is long, lasting from May to the end of September, and the monthly average temperature is between 22.4–29.9 °C; autumn includes October to November, and the average temperature is 13.3–19.6 °C; winter is from December to February of the following year, with an average temperature of 5–7 °C (Fig. 2). The extreme annual minimum temperature is −8.2 °C, and the maximum annual temperature is 41.6 °C. In general, the temperature in the four seasons of the city varies greatly, with hot and humid summers and cold winters. According to the climatic characteristics of Hangzhou, the rainwater garden can choose plants with strong flood resistance ability in plant selection and can use climatic conditions to produce unique scene effects at different times.

Hangzhou has been rainy for many years and belongs to a humid area. According to the analysis of the total annual precipitation in the “Hangzhou Statistical Yearbook” for 10 years, the average annual precipitation in the urban area of Hangzhou is about 1595.9 mm. The precipitation characteristics of Hangzhou urban area are mainly reflected in the following two aspects: First, the annual precipitation varies greatly, with a maximum rainfall of 1273.9 mm (Fig. 3). The difference between the maximum and minimum annual rainfall is 1.67 times, the minimum annual rainfall is about 0.8 times the average annual rainfall, and the maximum annual rainfall is about 1.34 times the average.

Secondly, rainfall shows the uneven distribution of rainfall for each month of the year. The precipitation is most concentrated from June to September, accounting for 50% of the annual precipitation. The monthly rainfall distribution presents the characteristics of Meiyu type and bimodal storm type rainfall. The rainy season lasts from March to July, and the monthly rainfall in June is the highest in the year, reaching 289.1 mm. The heavy rain lasted from August to October. This season was particularly severely affected by the storm, with increased rainfall and strong destructive power (see Fig. 4). After October, the precipitation decreases, and the precipitation in winter (December to February of the
following year) is the lowest in the whole year, accounting for only 15% of the annual precipitation. Hangzhou has abundant precipitation resources and has great potential for use. However, during the flood season and the impending stormy season, precipitation will increase rapidly, and the municipal drainage network will face tremendous pressure. Therefore, in terms of rainwater management, Hangzhou can combine green rainwater facilities with gray rainwater facilities to reduce urban flood disasters and other problems. The operation of rainwater gardens should pay attention to the infiltration capacity of rainwater and reasonably adjust the use of equipment according to the different environments in the area.

The soil types in Hangzhou include red soil, paddy soil, calcareous soil, yellow soil, and fluvo-aquic soil, mainly red soil and paddy soil. The texture of the soil cover is mainly clay, silt, loam, and so on. According to soil permeability, Hangzhou soil is mainly divided into two types: B type and C type. The infiltration rate is between 1 and 40 μm/s. Type B soil has better permeability. It must be protected during soil development to avoid soil enrichment; C type soil has low permeability and can be considered as construction soil. If it is necessary to build rainwater gardens and other treatment facilities, soil improvement should be carried out to increase the infiltration capacity (Table 1).

The upstream river network in downtown Hangzhou is covered. There are about 474 rivers with a total length of about 1021 km. The scale of the river network reaches 1.3 km/km². The main rivers are Q River, D’River, J Grand Canal, and so on. Among them, Q River is the largest water system in the city. Lakes are common, in Lake X, Lake Xiang, XX wetland, etc. Affected by the convenient river network system, the urban drainage pipe network is relatively short, relying on canals and pipelines to manage the flow of rainwater.

The impact of groundwater on rainwater is mainly reflected in two aspects: one is groundwater level, and the other is groundwater quality. The buried depth of groundwater in Hangzhou is about 0.5–3.5m, and the average buried depth of groundwater is 1.2 m. When constructing low-impact development facilities, access requirements must be met. In some areas with high water levels, the embedded green space must be impermeable to prevent groundwater from entering the device to affect the treatment efficiency, and to prevent runoff from affecting the quality of groundwater. The groundwater pollution in Hangzhou is relatively light, and the water quality is generally slightly alkaline, with a pH of 6.61–8.50 and an average pH of 7.51. However, its groundwater level is very high, and it is slightly polluted by surface water, so care must be taken to protect the surrounding environment.

The diversity of the underlying surface of Hangzhou Shangcheng determines the nature of urban runoff pollution and the complexity of the types of pollutants. According to the nature of the bottom of the basin, the function of the surface,
and the causes of pollutants, urban pollution sources can be divided into roof runoff pollution, runoff area runoff pollution, and road water pollution.

Zhu and other scholars conducted on-site investigations in Hangzhou and found that the water quality of the city’s natural rainfall reached classes II and III of the “Surface Water Cycle Standard.” The roof runoff pollution in the urban area of Hangzhou is heavy, and the initial runoff CODE is 6–9 times that of the last runoff. Li et al. tested and analyzed the runoff pollutants from four different land-use topography in Hangzhou’s traffic area, commercial area, residential area, and industrial area. In the initial runoff of 5–20 min, the maximum concentration of runoff particles reached a high value. After that, the concentration of runoff particles continued to increase with precipitation, showing an initial erosion phenomenon. In general, the average concentration of runoff pollution in Hangzhou urban area is much higher than the national water standard V, and the runoff pollutants are mainly COD and SS. The concentration of TP in the drain pipe is more than twice that of standard V grade water. NH₃-N also has varying degrees of pollution (Table 2). Especially in traffic areas, commercial areas, and industrial areas, runoff pollution is serious, and the operation of rainwater gardens should focus on controlling the quality of runoff. For rainwater gardens that control runoff pollution, water receptacles and runoff waste facilities should be set around them, and the collected runoff should be discharged into the pipe network within the first 10–15 min. Compared with other visible areas, runoff pollution in residential areas is minimal, and roof runoff pollution is affected by roofing materials. Ordinary asphalt, asbestos boards, and waterproofing materials will aggravate runoff pollutants; clay bricks and blue bricks do not contain runoff pollutants, and the value of rainwater collection is high; the roof garden has the ability to collect and clean runoff, and the effect is significant. It will also improve air quality and increase the city biodiversity. When the construction conditions permit, it should be used as the main management measure of roof runoff.

Calculation of the landscape area of rainwater reuse based on the climate characteristics of Hangzhou

For the calculation of the area of garden Y, the estimation method of the coverage ratio of the collected rainwater area can be used. In this section, the runoff coefficients of some coverage areas are summarized in Table 3. Consistent with the statistical data of different engineering plots of the Waterscape Park, the building area of each covered area is described in Table 4.

Discussion

Characteristics of rainwater process in Hangzhou

The natural manifestations of the rainwater cycle are mainly precipitation, evaporation, infiltration, and rainwater runoff. For residential communities, the total amount of rainwater resources available to the community is mainly determined

| Soil type | Soil composition | Water seepage rate, μm/s |
|-----------|------------------|-------------------------|
| A         | Sandy soil, loamy sand, sandy loam | ≥ 40 μm/s |
| B         | Silty loam, loam | 10 m/s-40 μm/s |
| C         | Sandy clay loam  | 1-10 μm/s |
| D         | Clay loam, silty clay loam, silty sand, sandy clay, clay | ≤ 1 μm/s |
by precipitation, rainwater infiltration, evaporation, and surface drainage.

The rainfall in Hangzhou is uneven throughout the year, mainly from April to September, which accounts for almost 65 to 75% of the annual rainfall; Hangzhou has two rainy seasons throughout the year: the first rainy season is from early May to July. At the end of the first 10 days of each month, it is called the flood season. During this period, continuous precipitation was concentrated, with an average precipitation of 350–550 mm, accounting for about 25–31% of the annual precipitation. The second rainy season occurs from the end of August to the end of September. Affected by the typhoon, rainfall was concentrated. The average rainfall is 120–220 mm, accounting for 8–13% of the total annual rainfall. These two rainy seasons lead to rapid accumulation of urban water, so higher requirements for urban drainage are put forward.

The central area of Hangzhou is located on the rocky bank of the lower reaches of the Q River, the transition zone from ZX hills to ZB plain. The terrain is high in the southwest and low in the northeast. The height of the hill is generally between 50 and 400 m. It is bounded by a line with B Mountain-W Gate-G Dang. There are many lakes and ponds on the north and west sides of the water network. The elevation of the plot is 2–5.5 m. The southeast is the main built-up area of the city, and the elevation is 4.5–4.7 m. Surrounded by mountains on three sides and river on the other, the flat terrain in the middle increases the difficulty of urban natural drainage. Therefore, the municipal pipe network is mostly used in Hangzhou. If the rainfall is concentrated and the drainage pipe network standard is short, it is easy to cause stagnant water and even cause serious disasters such as urban waterlogging. In recent years, due to the destruction of the environment by urbanization, rainfall has become more abundant, and urban waterlogging has often occurred.

The urban area of Hangzhou is a soil type suitable for rainwater infiltration. The soil environment is very important for rainwater infiltration rate and plant selection in residential areas. Soil permeability is the key to measuring whether the area is suitable for rainwater infiltration. There are 5 types of soil in Hangzhou: red soil, lime soil (stone), bone soil, fluvo-aquic soil, and paddy soil. The base of the soil is usually clay loam, silt loam, loam, and loamy loam. According to the hydrological permeability of the soil, the soil can be divided into four types: A, B, C, and D. The soil texture types in Hangzhou belong to B and C types, and the water runoff rate is 1–40 μm/s. According to the requirements of rainwater infiltration, the soil permeability should be in the range of 1–1000 μm/s. Therefore, the rainwater infiltration conditions in the urban area of Hangzhou are better and suitable for treating the source of rainwater.

According to the first three characteristics of the region, rainwater management in Hangzhou residential areas is also suitable for using underground runoff and some rivers. The fourth rainwater standard needs to pay attention to the purification of rainwater in the process of infiltration and reuse, so as to meet the rainwater use standard. The current rainwater purification has high requirements for equipment economy. The use of natural landscapes to improve purification and cleanliness is ecologically sustainable. In Hangzhou rainwater community management, the organic combination of rainwater management and environmental landscape should be emphasized.

| Underlying surface type                                      | Rainwater runoff coefficient |
|--------------------------------------------------------------|-----------------------------|
| Hard roof, asphalt roof                                      | 0.8–0.9                     |
| Concrete and asphalt roads                                   | 0.8–0.9                     |
| Greenbelt covered with soil for underground buildings (thickness of soil ≥ 500 mm) | 0.15                         |
| Block pavement                                               | 0.5–0.6                     |
| Dry brick and gravel pavement                                | 0.4                          |
| Green space                                                  | 0.15                         |
| Water surface                                                | 1                            |
Landscape design methods for rainwater reuse in different land-use spaces

In 2019, the average pavement area rate in Hangzhou’s built-up area was 12.93%, and by 2020, this indicator will reach 15%. As a large area of impermeable asphalt pavement in cities, the rainwater flow and runoff pollution provided by the rainy season will greatly test the safety of the water environment. Rainwater runoff flows directly from the roads in Hangzhou and is discharged from the city’s rivers through canals and municipal pipelines. The first stage runoff pollution is serious. If it is discharged directly into a stream, it will pollute the water to a great extent. Therefore, the urban drainage pipe network must first divide rainwater and sewage, and the rainwater discharged in the initial stage is directly transported to the sewer pipes, collected and cleaned by the treatment plant, and discharged. Secondly, the rainwater runoff after the initial discharge is collected on both sides of the road, rainwater garden in the green belt for process treatment, such as retention, cleaning, and purification, to minimize pollution.

Road greening mainly refers to the degree of purification of the green belts in the middle and on both sides of the road, including the greening of road traffic. Nowadays, most of Hangzhou’s green space is separated from urban roads by curbs, which are designed to quickly accumulate runoff in the middle valleys on both sides of the road and easily discharge from municipal water network pipelines. Even if this channel design method is fast, it has a better green landscape effect, if there is a heavy rainy season, it will exceed the transportation capacity of the municipal pipeline, resulting in serious water accumulation on the road. A common method of combining rain gardens with roads is to design the road green space as a recessed green space smaller than the height of the road. The teeth on the roadside are connected or open to a certain extent, and overflow facilities are set up to place it in the green space. Runoff exceeding the carrying capacity will be transported to the urban pipe network through the discharge outlet (Fig. 5).

Building roofs are mainly divided into flat roofs and pitched roofs. The roof of the building is the main source of rainwater runoff. Traditional building roofs are usually covered with waterproof membranes. Based on this, we should vigorously promote the construction of roof greening to improve the urban ecological environment. Flat roofs or roofs with a slope of at least 15° should be constructed using roof gardens. Roof greening not only makes a great contribution to the green construction of the city, but also filters and absorbs rainwater. Rainwater exceeding the storage capacity flows into the water storage facility of the building below and enters the water storage facility through the rainwater pipe. The rainwater generated by the sloping roof and other buildings is connected to the auxiliary green area of the building through the downspout, rainwater garden, and green grass canal, and organized rainwater flows into the rainwater garden for treatment. At the same time, attention should be paid to the transfer of rainwater and domestic sewage, as well as the installation of sewage pipes connected to sewer pipes (Fig. 6).

The rain garden should be combined with the topography. The topography of the park is continuously undulating, and the rainwater garden should have a more accurate understanding of the topography of the site before site selection and construction. If the slope of the site is relatively slow, the rain garden can be directly transformed on the basis of the original topography, and the micro-topography can be used to collect rainwater. After a simple infiltration treatment, rainwater flows into the underground water storage tank through the rainwater pipe for later use. During heavy rainfall, excess rainwater is collected through rainwater flow pipes buried along the edge of the green space, and then discharged through rainwater pipes (Fig. 7).

If the slope of the site is high, the topographical changes can be combined with the construction and transformation of rainwater garden terraces. Rainwater is intercepted and purified at different heights of storage compartments. Visualize the process of rainwater treatment through walls, water curtains, and other forms.

As a distribution center for the flow of people, the city square needs a large number of paved areas to meet the needs of use. Due to the small area of market green space, it is easy to produce a lot of rainwater runoff when it rains. In some built-up squares, rainwater is directly discharged through sewer pipes, and the storage and utilization of rainwater has not

| Underlying surface type                                      | Underlying surface area (m²) |
|--------------------------------------------------------------|------------------------------|
| Hard roof, asphalt roof                                     | 1075                         |
| Block stone, king brick pavement                             | 16,050                       |
| Water body                                                   | 24,270                       |
| Greenbelt covered with soil for underground buildings (thickness of soil ≥ 500 mm) | 4400                         |
| Green space                                                 | 44,315                       |
been fully considered. The existing square can be transformed into a rain garden. The rainwater flowing into the square is introduced into the rainwater garden through the dispatch facility for collection, treatment, and reuse. The purified rainwater is stored in the water storage building and can be sprayed on the square to irrigate the green space.

For some urban construction sites with tight land-use and high flood control requirements, the construction of sunken squares can increase the area of activity in the area and can collect and store rainwater. In the case of short rainfall, rainwater can enter the rainwater garden and deep asphalt without affecting its practicality. In case of heavy rain, the market can be used as a large rainwater storage facility to temporarily store rainwater, and then slowly infiltrate into the drainage network. In order to ensure safe use in the market, the water level should be marked, and safety precautions should be taken when the water level is high to prevent dangerous situations such as children from entering (Fig. 8).

The process of rainwater reuse in landscape design

According to the difference in soil surface permeability and the ability to resist runoff pollution, rainwater gardens can be divided into two forms: simple (no need to replace the soil) and complex (replacement of the soil). The latter rain garden is often used in heavily polluted areas such as roads, green spaces, shopping malls, and parking lots in Hangzhou. Take the latter as an example to discuss the specific process of its construction.

Preparation before construction

(1) Before construction, delimit the covering layer of the building to prevent soil adhesion. If the site needs a larger rainwater garden area to meet the use needs, more small rainwater gardens should be designed to improve its use efficiency.

(2) Water and soil conservation measures should be taken in the waterway basin to avoid damage to the rain garden due to excessive water and soil flow.

(3) Carry out detailed inspections of necessary materials such as sewer pipes, discharge pipes, gravel, geotextiles, soil substrates, and vegetation, to ensure that they meet the requirements for use.

(4) After cleaning the site, check whether there is water in the area, and then continue to work.

Earthwork and main engineering construction

(1) The site should be excavated step by step, adopting horizontal excavation method to avoid soil compaction and adopting vertical excavation on both sides. After excavation, the flatness of the area should be reduced. For municipal roads with poor soil quality, such as submerged soil, rainwater gardens should be treated with anti-seepage treatment. Geotextile and impermeable membrane must be laid on the bottom and sides. The quality of the anti-permeation membrane shall not be less than 300 g/m².
Laying a layer of 250–300-mm-thick gravel, the diameter of the gravel should not exceed 50 mm, nor too small; must the top gravel be washed clean before laying to prevent mud clogging of the laying pipeline.

Installation of perforated drainage pipe (DN100-150) and installation of discharge device. The length of the perforated drain pipe must be covered with at least 80-mm-thick gravel; the discharge port must be covered with a network and other wastewater control devices, and the height of the discharge port must be less than the water area of the tank to ensure that excessive rainwater can be discharged (Shao et al. 2020).

Lay a permeable geotextile layer or a 100-mm-thick sand layer on the gravel layer to prevent soil and filler particles from entering the gravel layer and prevent the pipeline from being blocked (Sun et al. 2015).

Filling with artificial filler or sandy soil with good air permeability. Some areas of Hangzhou have low soil permeability, so it can be considered to add slag, ceramsite, and other materials with higher permeability to the undisturbed soil as an improvement measure.

Before laying the surface substrate, the permeability of the substrate must be tested to confirm its permeability (Tang et al. 2020).

Soil planting provides essential nutrients for plant growth. A fertile soil with an organic content of about 5 to 10% and an allocation ratio of 60 to 85% will be selected (Tao et al. 2019). The thickness of the soil layer depends on the plants grown. When choosing seedlings, the thickness is usually not less than 250 mm; when choosing small trees, not less than 450 mm; and when choosing shallow rootstocks, not less than 1000 mm.

Precautions for water and soil conservation

To prevent hardening and erosion of the planted soil surface, the surface is usually covered with bark and leaves 50–80 mm thick.

The slope above the top of the planting soil should be greater than 3:1 to reduce the flow. The inlet area of the...
rainwater garden should be equipped with energy dissipation devices.

(3) After the first-level high-intensity rainwater treatment, part of the water body can be placed in the garden rainwater pipeline to prevent rainwater runoff. Excess rainwater will flow into urban pipelines.

**Operation and maintenance of rainwater reuse landscape**

The maintenance of rainwater garden is mainly about environmental cleaning, regular disposal of collected waste, timely verification of drainage and infiltration, and maintenance and management of plants (Table 5).

Establish a maintenance management process, maintain training for employees before the facility is set up, and record the work content over a period of time (Transon et al. 2018). Before the rainy season comes, continue to inspect and inspect the rainwater garden to ensure that the garden is in good condition after the rain. In the rainy season, check the rainwater garden regularly and replace damaged materials in time (Vincent et al. 2010).

The management department can monitor the operation of the rainwater garden for a long time. Through field tests and data collection, the rainwater garden can be tested for its ability to control flow and remove pollutants and provide a scientific basis for the construction of landscape rainwater collection and rainwater reuse (Wang et al. 2017).

### Table 5  Inspection and maintenance content table of rainwater garden

| Check content                                                                 | Inspection cycle                                                                 |
|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| Plant growth status, density, diversity, and dryness of soil from diseases and insect pests | Once a month within 2 years after completion, 4 times a year thereafter. 4 times a year. |
| Whether the rainwater runoff inlet is blocked or damaged by scouring, check whether there is siltation in the overflow facility | Four times a year within 2 years after completion, and 2 times a year thereafter, or within 24 h after heavy rain. |
| Whether there is silt in the water storage area, whether the slope is collapsed, and whether the overflow is unobstructed | |
| Whether the rainwater emptying time is more than 48 h | |
| Water quality Maintenance content                                            | Maintenance cycle.                                                                 |
| Replant plants and remove weeds and dead and diseased plants                  | At least twice a year.                                                            |
| Build plants, harvest vegetation, water plants in time, apply top dressing, and debris and garbage cleaning | Depends on inspection results.                                                   |
| Trimming the covering layer and replacing the covering layer                 | Depends on inspection results.                                                   |
| Replace surface planting soil, geotextile, or sand filter layer               | Once a year, depending on inspection results.                                    |
|                                                                                 | The inspection results show that the filter layer and underground drainage layer are out of function. |

The rainwater garden can be supplemented with professional knowledge to increase the public’s awareness and recognition of sustainable development by introducing the operation of facilities and demonstrating rainwater treatment technology.

**Conclusion**

According to the more in-depth research on low-impact development and rainwater garden theory, it is helpful to obtain data and investigate the basic natural conditions and current situation of the Hangzhou rainwater management project and investigate the factors that affect the construction of Hangzhou rainwater garden, such as large volume and groundwater (Wu and Prasad 2017), shallow location, poor soil permeability, and serious rainwater pollution; strengthen the construction strategy of Hangzhou rainwater garden construction systems and finally, proposed the anti-pollution of rainwater garden and apply it to buildings, roads, parks, and square spaces, and proposed the overall. The construction process and management, as well as the construction and operation and maintenance of the rain garden, are sustainable. In a practical case, based on the construction principles and strategies previously proposed, the current situation of the area was investigated and analyzed, and the conclusion was that the location of the rainwater garden was set up to prevent the runoff pollution of the park as the main purpose. Then, analyze the topography of the area and draw the main area map.
captured in the area and calculate and verify the surface area of rainfall flowing in the area to obtain the necessary measurement of the rain garden. During the planning and design, detailed planning was carried out on areas prone to water accumulation in the park, and a rainwater management method combining permeable pavement, permeable drainage canal, planting ditches and plants, and other related measures was proposed for low-impact development.

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Declarations

Conflict of interest

The author declares that she has no competing interests.

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