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DESIGN AND WATER-SAVING CAPACITY OF PLANTING ROOF WITH COMPOUND IRRIGATION AND STAB-RESISTANT FUNCTION

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Highlights:

- this new planting roof's stab-resistant and water-proofing layer abandoned traditional coatings and coiled material, and achieved its stab-resistant and water-proofing function by using roof structural slabs and rigid sloping layers;
- a water filtering layer with adjustable water storage capacity was designed and a microscopic design of the roof landscape was carried out, which improves the water-saving ability and contributes to the popularization and application of planting roof;
- the Penman-Monteith method and the garden coefficient correction method were used to measure the water demand of roof plants and study the irrigation water-saving capacity of this planting roof theoretically.

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Abstract. With the continuous development of urban construction, the contradiction between human settlement and the natural environment is becoming increasingly prominent. Increasing the green area and improving the local environment and microclimate through roof planting can effectively alleviate this contradiction. On the basis of the research on the current situation and challenging problems of planting roofs, a comprehensive study of construction, stab-resistance, waterproofing, irrigation and plant landscape is combined with a designed roof case. Research results show that the planting roof is simple in construction, has high resistance to plant root thorns, can take into account the function and aesthetics of plant landscape design, and saves irrigation water by more than 60%, which will help the popularization and promotion of urban planting roofs.

Keywords: compound irrigation, roof stab-resistance, roof structure, planting roof, landscape design, water-saving capacity.

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1. Introduction

Since the reform and opening up of China in the 1970s, China has experienced an unprecedented expansion of urbanization at an increasing rate (Yang et al., 2014). At the same time, many urban environmental problems have arisen, and one of the most significant problems is the urban heat island effect. The heat island effect becomes more pronounced in more densely built-up urban areas (Chen et al., 2018), thus having profound implications for urban energy and the health of its inhabitants (Li et al., 2022b). Increasing the city's green area is usually considered one way to solve the problem (Cai et al., 2011; Wong & Yu, 2005). However, urban land area is limited, and the ability to expand urban green space is more limited. In the background of scarce urban land resources, planting roof construction is an important strategy to alleviate the urban heat island effect and improve urban air quality (Li & Babcock, 2014).

Compared with traditional roofs, the flexible waterproofing layer of planting roofs is easily punctured by the plant's roots. Existing studies have attempted to apply waterproofing coiled material such as modified bitumen, polyvinyl chloride (PVC), and ethylene-propylene-diene monomer (EPDM) in planting roofs (Cascone, 2019; Wang et al., 2015) or use root caps to prevent root penetration of the roof waterproofing layer (Bass, 2008). However, this coiled material, which has stab-resistant and waterproofing properties, has too many construction layers, a complex construction process, and a high economic cost (Zhang et al., 2009). As organic materials, the service life is short, aging or breakage occurs easily (Zhu et al., 2015), and rework will damage the roofing landscape. The selection and application of roof plants have also become the focus of current research due to the limitation of the structural bearing capacity of planting roofs and their particular environment. Many studies have been conducted to study the adaptability of various plants in different climatic environments from the perspective of plant characteristics by means of experimental monitoring (Liu et al., 2012; Li et al., 2022a; Petra et al., 2020), to provide a reference for the selection of plant for planting roofs in different climatic environments. Some studies also emphasize human-centered, ecologically green, and environment-oriented planning and design concepts from the perspective of landscape art design and elaborate the selection and layout of planting roof plants (Chen, 2020; Jing, 2014). However, the studies are more general and macroscopic, rarely integrating the microstructure of roofs with landscape design. In addition, planting roofs are more than 10 meters or even tens of meters from the ground, the wind speed on the roof is high, water evaporates quickly, and the planted soil layer is thin and weak at water retention (Cao et al., 2013), thus requiring frequent watering of roof plants. To solve this problem, studies have applied microfiber percolation irrigation technology to planting roofs to improve the water-holding capacity of roof soil and air moisture adsorption (Wu et al., 2022). Some studies used light organic waste such as coarse coconut shells, delicate coconut shells and gardening waste compost as roofing substrate to enhance its water retention performance (Xue & Farrell, 2020). Other studies explored the feasibility of using roof rainwater to irrigate roof plants and designed a roof rainwater collection and utilization system using underground water pond storage (Cao et al., 2013). In general, A great planting roof relies on the combination of the sciences of stab-resistance, waterproofing, horticulture and engineering (Lin et al., 2013).

On the basis of existing research and combined a designed case, this study analyzes a planting roof design with compound irrigation and stab-resistant function and its water-saving capability from a microscopic perspective. The traditional flexible coiled material of the planting roof's stab-resistant and waterproofing layer are removed, and the roof structure plate and rigid slope layer are used to achieve its stab-resistant and waterproofing function. On this basis, a planting roof water storage and irrigation system is designed, the system's water-saving capacity is analyzed, and a more microscopic roof landscape design is developed.

The possible contributions of this study are as follows: First, this study overcomes the shortcomings of the traditional planting roof, such as coil aging and the high cost of construction. Second, the planting roof achieves water-saving irrigation, taking into account the function and aesthetics of plant landscape design, improves the feasibility of planting roof applications, and contributes to the further promotion and popularity of planting roofs.

2. Problems faced by traditional planting roof

2.1. Stab-resistance in roof construction

Planting roofs are roofs that are planted with plants to make them waterproof, provide them with heat insulation and thermal insulation properties, and achieve eco-friendliness. A water-proofing layer is applied on the roof of the building or the project (Liu et al., 2019). The traditional planting roof has a flexible waterproofing coiled material and a stab-resistant layer underneath the soil layer. Thus, it has too many structure layers and a complex construction process, and is prone to aging or breakage during long-term use, resulting in roof leaks. Currently, the main planting roof in the market uses a waterproof coiled material and a stab-resistant layer. Zhang's (Zhang & Hu, 2018) research on Shandong Weifang Cultural Arts Center planting roof; Jiang's (Jiang et al., 2018) research on the Tianhe Airport Transportation Center's super large-scale planting roof; Li's (Li & Qin, 2017) research on the 5–12 Wenchuan Earthquake Memorial Hall planting roofs; and the planting roof in the Technical Specification for Planting Roof are all such roofs (Ministry of Housing and Urban-Rural Development, 2013). Therefore, a problem that is worth further exploration is how to reduce the construction level of planting roofs and solve the plant root penetration problem more effectively.

2.2. Restrictions on the species of roofing plants

The selection of plant species is limited because of the particularity of the roof environment (Vijayaraghavan, 2016). Especially for selecting plant species on the roof of existing buildings, the designer needs to design the planting plan after inspecting the roof to achieve the unity of safety, artistry, and aesthetics of the planting roof. In terms of safety, the roof structure has a limited bearing capacity, and in the selection of planting roof plants, not only the permanent load at the time of initial planting but also the increased live load when the plants grow needs to be considered. The increased live load when the plants grow is much higher than the permanent load at the initial planting and is difficult to quantify. Thus, when selecting plant species, plants with smaller weights for later growth should be chosen. In addition, compared with the ground wind, the wind is stronger on the roof of high-rise buildings, especially in coastal areas where wind damage is more serious, and the wind directly affects the expected growth of plants. Thus, wind-resistant plants should be chosen. In terms of artistry and aesthetics, planting roofs should create a sense of moving mountains and flowing water, and an image of hills and valleys. Different plants can give people a different artistic feeling, but the restriction of plant species limits the choice of planting roof design schemes. How to reduce the planting load of the roof, improve the wind resistance of roofing plants, considering the artistry and aesthetics of the roof landscape, and expand the range of plant species selection are problems that must be considered when designing planting roofs.

2.3. Exploitation of roof rainwater

Currently, an acute contradiction exists between the supply and demand of water resources in China. The total water resources in China account for 6% of the world's total water resources, but the per capita water resources are only one-fourth of the world's total per capita water resources (Yu, 2020). At the same time, many cities in China are prone to extreme weather and severe urban waterlogging. The development and utilization of rainwater from planting roofs can positively alleviate urban water stress and reduce urban waterlogging (Contreras-Bejarano & Villegas-González, 2019; Gan, 2015). However, the effective development and utilization of rainwater from planting roofs face many problems. First, the degree of roof rainwater development and utilization is low (Zuo et al., 2018). Most planting roof rainwater is directly lost through surface runoff, and the planted soil layer can absorb limited rainwater. Moreover, the transpiration of roof plants and soil evaporation need to consume more water, and frequent manual watering has caused much inconvenience to the management of roof plants. Second, waterlogging of roofing plants easily takes place (Jin et al., 2019). In the rainy season, many planting roofs are seriously waterlogged inside and on the surface of the soil layer due to the unreasonable drainage design of planting roofs when continuous heavy precipitation occurs, which easily causes plant waterlogging problems and affects the expected growth of plants. Therefore, in terms of how to more fully and effectively utilize planting roof rainwater resources, further reduce the cost of roof plant management and the frequency of plant waterlogging, which are particularly important for the further development and promotion of planting roofs in the future.

3. Study case

Nanchang (115°27′E–116°35′E, 28°09′N–29°11′N) is located in East China, north of central Jiangxi province, with a subtropical humid monsoon climate. The climate is humid and mild with sufficient sunshine, which is suitable for the development of planting roofs, and there have been several relevant cases of planting roofs. The effect of the completed planting roof is shown in Figure 1.

Therefore, this paper combines a designed case of residential roof to analyze the planting roof with compound irrigation and stab-resistant function. The case is as follows: a residential building in Nanchang with six floors and a roof area of 1440 m^2, including 1168 m^2 of green space and 272 m^2 of water pond and elevator machine room. The roof is decorated with garden plants and landscape sketches, and the garden plants include salvia splendens, laurus nobilis, and red maple; the garden sketches include landscape stones, wood pavilion, and stepping stones. The plan layout is shown in Figure 2.

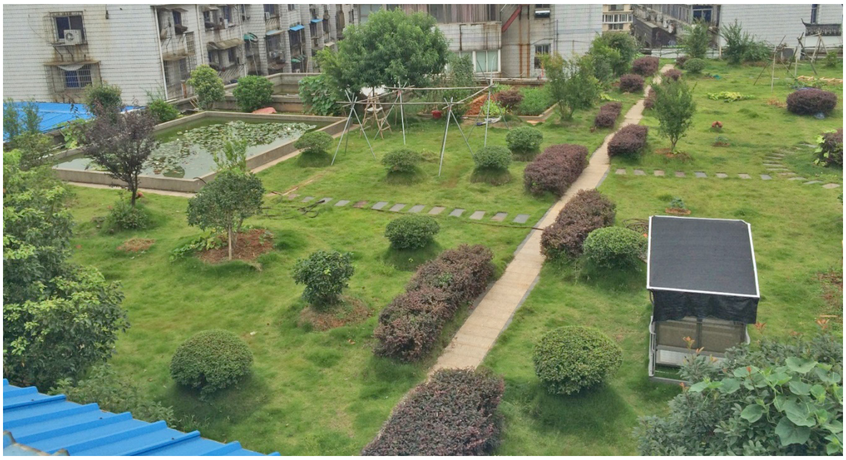

Figure 1. A planting roof in Nanchang, Jiangxi province

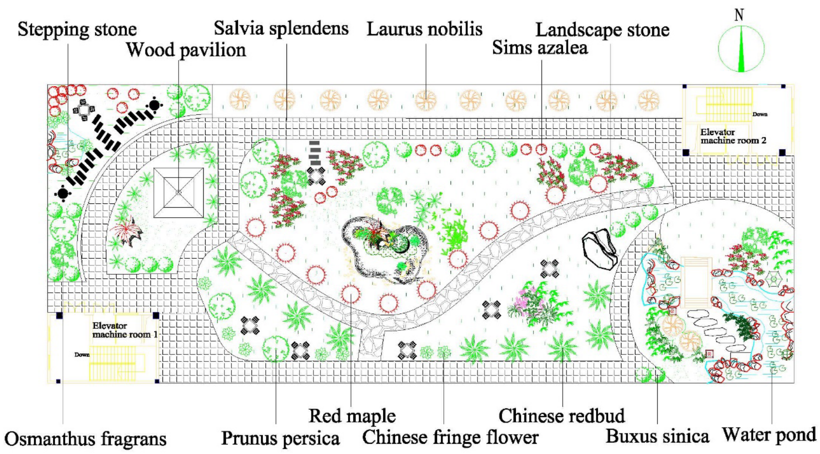

Figure 2. Planting roof landscape design schematic

3.1. Roof construction

The bottom-up construction of the planting area for the study case in this paper includes roof structural slab, sloping layer, water filtering layer, geotextile layer, planting soil layer, and plant layer (Fan & Mi, 2017), as shown in Figure 3.

(1) Roof structural slab: It is cast-in-situ reinforced concrete, which is the main waterproofing component and has a self-waterproofing capability.

(2) Sloping layer: It is a reinforced concrete sloping layer with a slope of about 5‰, the thinnest part is not less than 20 mm, and the waterproofing agent is Φ4@150 steel wire mesh. Appropriate radial bars are arranged in the corner area of the crack-prone slab.

(3) Water filtering layer: It is located above the sloping layer and consists of a cinder with an average thickness of not less than 80 mm.

(4) Geotextile layer: It is located above the water filtering layer to prevent the upper layer of soil from entering the cinder filter layer.

(5) Planting soil layer: Clay with minerals is used (Wu et al., 2012), which is laid above the geotextile by an average thickness of not less than 80 mm. A composite drainage storage system and intelligent spraying system consisting of inspection wells, and various drainage pipes are laid in the planting soil layer and water filtering layer.

(6) Planting layer: This layer is mainly planted with flowers and trees suitable for growing on the roof, and healthy trails such as gravel and stepping stones are laid on the main pathways.

The above roof was waterproofed directly with a reinforced concrete structural slab, and a reinforced concrete fine stone sloping layer was placed on top of it, followed by the cinder water filtering layer and a planting soil layer. The reinforced concrete slope layer serves to define the slope, further strengthen the waterproofing, and prevent plant roots from piercing the waterproof layer, which can well overcome the shortcomings of traditional planting roofs.

3.2. Roof landscaping

Planting roof landscape design is a sustainable landscape created by regenerative design based on the self-organic renewal capacity of natural systems with planting roofs as the object. The structure of the underlying surface of the roof planting area directly affects the function of the planting roof and the safety of its use. This study's roof case can effectively store water to irrigate the vegetation and protect the roof from damage to the vegetation root. Unlike traditional planting roofs, which have limitations in vegetation selection and landscape shaping, this type of planting roof allows for a wider variety of plant species and a better balance of plants with different functions and growth forms, to enhance the performance of the planting roof system and the diversity of the landscape (Heim & Lundholm, 2014). A unified and rhythmic design can be formed through different combinations of scenic walls, hedges, garden paths, and plantings of trees, shrubs, and grasses, with appropriate scales and simple structures to facilitate people's participation in the design of planting roofs and increase the interactivity of the place. It can also be designed in a streamlined shape, with spacious open areas and surrounded by grass, trees, and shrubs to form a flowing and cohesive space, providing a space for residents to relax and communicate.

This paper's study case considers the planting roof's resting and ornamental function. With the use of a natural design, the vegetation is mainly low shrubs planted with local micro-topography, forming a staggered and layered plant landscape. Plant species are used primarily in leaf type and strain type of beautiful evergreen plants so that the planting roof has scenery throughout four seasons and flowers for three seasons, reflecting the garden landscape's colorful seasonal changes. For later management, native plants adapted to local climate characteristics should be used, such as salvia splendens and laurel. This case pays attention to the overall harmony of the planting roof landscape and the interest in the overall landscape. In the study case, aside from a circular walkway in line with the greenery on the roof, additional paved and stone paths are available to give visitors different viewing experiences. At the same time, it is also equipped with seats and square wooden pavilions to provide a resting place for visitors to enjoy the scenery. To enrich the spatial hierarchy and reflect the regional humanistic background, the southeast corner of the planting roof is set up as a water courtyard, surrounded by greenery, sparkling water and vegetation. Small bridges and scenic stones are arranged

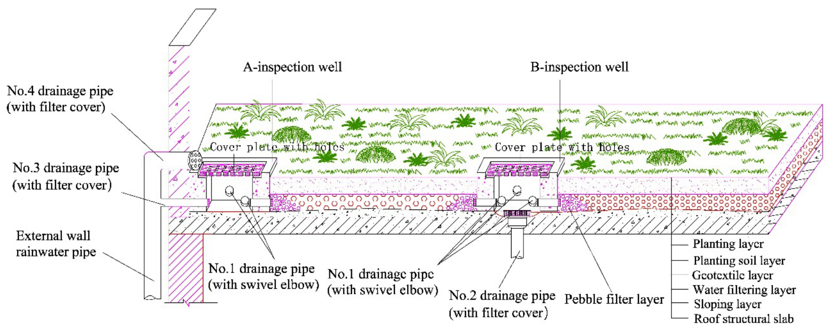

Figure 3. Schematic of the planting roof structure

in the courtyard, which can not only highlight the scenery but also complement the environment. Considering the limitation of the load-bearing capacity of the planting roof, the scenic stones are fake plastic stones placed after the garden environment is formed.

3.3. Roof compound irrigation

As shown in Figure 3, roof rainwater can be discharged through A-inspection wells, B-inspection wells, and No. 4 drainage pipe; rainwater and irrigation water in the water filter layer can be removed through the Nos. 1 and 3 drainage pipes. To enhance the water storage capacity of the planting roof, the inlet end of the No. 1 drainage pipe in the cinder filter layer (with filter cover and pebble filter layer) is connected to the filter layer. The outlet end extends into the inspection well (with swivel elbow), and the bottom of the pipe can be 30–50 mm higher than the sloping layer as needed. According to the precipitation situation, the water storage capacity of the filter layer can be controlled by adjusting the height of the rotating elbow of the drainage pipe in the inspection well to realize the dynamic water storage function of the planting roof so that rainwater resources can be fully utilized and sufficient water can be provided for plant growth. In addition, an intelligent spraying system is installed in the planting soil layer, and the vertical intelligent spraying system is 80–100 mm higher than the planting layer. When there is not enough water in the filtering layer, the intelligent spraying system can be turned on to realize its compound irrigation function.

4. Water-saving capacity

The study case has a composite irrigation function. The manager can rotate the rotating elbow of the inspection well pipeline according to the actual needs, adjust the water storage capacity of the filter layer, ensure the availability of water required for plant transpiration, and realize the full utilization of rainwater resources. According to the calculation, the study case can save 66.49% of irrigation water, thus having a certain popularization value.

4.1. Methods and materials

Plant water demand is an essential basis for quantifying the water-saving capacity of planting roofs. This paper uses the Penman–Monteith equation for measuring the plant water demand for the study case, which FAO recommends for accurate measurement of the reference crop water demand (Jing et al., 2022). The calculation equation is as follows:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s + e_a)}{\Delta + \gamma(1 + 0.34U_2)}, \quad (1)$$

where ET_0 is the reference crop water requirement, mm; R_n is the net radiation, MJ/(m^2·d); G is the soil heat flux, MJ/(m^2·d); γ is the hygrometer constant, kPa/°C; T is the air temperature, °C; U_2 is the wind speed at 2 m height, m/s; e_s is the saturated water vapor pressure, kPa; e_a is the actual water pressure, kPa; and Δ is the slope of the relationship between saturated water pressure and air temperature, kPa/°C.

First, after the reference crop water requirement ET_0 was calculated, it was then adjusted according to the actual situation of the planting roof using the garden coefficient method (Qiu & Guan, 2011) to obtain the actual plant water requirement.

$$ET = ET_0 \times K_S \times K_d \times K_{mc}, \quad (2)$$

where ET is the actual plant water demand, mm; K_s is the plant species coefficient; K_d is the planting density coefficient; and K_{mc} is the microclimate coefficient.

Then, the maximum water storage capacity of the planting roof was calculated (Chen et al., 2015).

$$W_w = S \times D \times H \times w \times 10 / 1000, \quad (3)$$

where W_w is the maximum water storage capacity of the filter layer, m^3; S is the area of the filter layer, m^2; D is the capacitance of the filter layer material, g/cm^3; H is the thickness of the filter layer, cm; and w is the water content of the filter layer material, %.

Finally, the final water-saving capacity of the study case is obtained by combining the already calculated plant water demand with the maximum roof water storage and the annual precipitation.

$$EF = 1 - \frac{V}{ET_a + EP}, \quad (4)$$

where EF is the water saving capacity, %; ET_a is the total annual water demand of plants, m^3; EP is the evaporation of stored water, m^3; and V is the irrigation water consumption, m^3.

The meteorological data of temperature, barometric pressure, wind speed, and precipitation are the annual monitoring data of meteorological station No. 58606 in Nanchang for 2019, which were obtained from the National Meteorological Science Data Center in China.

4.2. Results

4.2.1. Plant water requirement

To calculate the water requirement of planting roof plants, garden adjustment coefficients such as plant species, plant density, and microclimate need to be determined. Relevant reference divided each garden adjustment coefficient into high, average, and low values (Qiu & Guan, 2011), and this study referred to its division standard, combined with the actual planting situation of the roof case; the adjustment coefficient of plant species was 0.5, and the adjustment coefficients of plant density and microclimate were 1. Equation (1) was used to obtain Nanchang's reference crop water requirement in 2019. Then, according to the garden adjustment coefficients of

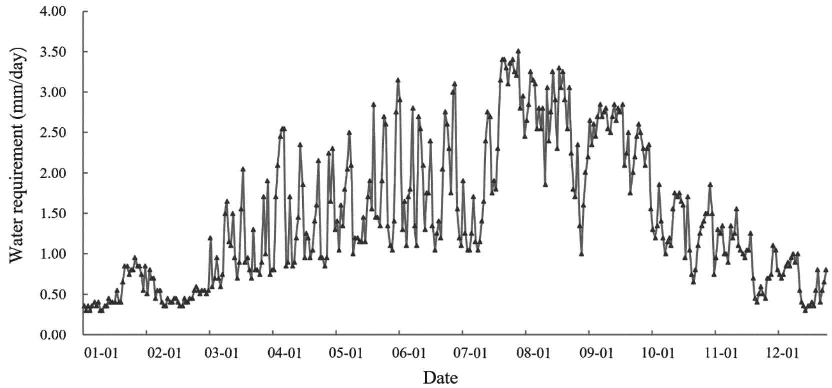

Figure 4. Daily water requirement of plants

plant species, plant density, and microclimate, the actual water requirement of plants in the roof case was calculated by Equation (2).

As shown in Figure 4, the plant daily water requirement from January to August is in the rising stage, among which the inter-day variation of plant water requirement is pronounced from March to July due to the overall increase in temperature, and the inter-day weather change markedly. From September onwards, the daily weather variation was relatively stable, with a general decreased trend in total plant water requirement and inter-day fluctuation.

The specific data in Table 1 show that the actual plant water requirement varies more significantly from month to month. The minimum plant water requirement was 15.70 m^3 in February, but the plant water requirement reached 99.57 m^3 by August, and the total plant water requirement reached 622.31 m^3 in 2019. The plant water requirement in this area varies greatly not only from day to day but also from month to month. Therefore, realizing the water storage function of the planting roof is of great practical importance to maintain plant transpiration and save water resources.

Table 1. Monthly water requirements of plants

Month	ET_{0a} (mm/day)	ET_a (mm/day)	Total ET_a (mm)	Total ET_a (m^3)
January	1.07	0.54	16.74	19.55
February	0.96	0.48	13.44	15.70
March	1.98	0.99	30.69	35.85
April	2.79	1.40	42.00	49.06
May	3.33	1.66	51.46	60.11
June	3.75	1.88	56.40	65.88
July	4.29	2.15	66.65	77.85
August	5.50	2.75	85.25	99.57
September	4.77	2.38	71.40	83.40
October	2.93	1.47	45.57	53.23
November	2.15	1.07	32.10	37.49
December	1.35	0.68	21.08	24.62

Note: ET_{0a} and ET_a are average reference crop water requirement and average actual plant water requirement, respectively.

4.2.2. Roof water storage

To prevent roof plants from long-term waterlogging, which affects their normal growth, the water storage layer is mainly the water filter layer. When the water storage height is higher than the layer, the excess water will flow into the inspection well from the rotating elbow and not infiltrate into the planting soil layer. Therefore, this study measures only the maximum amount of water that can be stored in the water filter layer. The total area of the roof in this case, after deducting the area of the pool and the elevator room, the total area of water storage in the filter layer is 1168 m^2. The cinder in the filter layer has a volume weight of 0.98 g/cm^3, an average thickness of 80 mm, and a water content of 55%. The maximum water storage capacity of the roof is 50.36 m^3 as calculated by Equation (3).

4.2.3. Roofing water-saving capacity

Nanchang is located in East China and belongs to subtropical humid monsoon climate with prominent seasonal precipitation characteristics. Its precipitation from January to May and from May to July show the characteristics of rising-falling, accounting for 68.98% of the total annual precipitation. In 2019, the highest precipitation was 329.90 mm in June, the lowest precipitation was 5.70 mm in October, and the total yearly precipitation reached 1613.4 mm.

Referring to the relevant literature (Xiong et al., 2004; Zhu et al., 2016) and considering the actual situation of the study case, the rainwater infiltration rate was 40%, and the water storage evaporation and plant water requirement were calculated according to the 1:3 distribution. Under the premise that the maximum storage capacity of the planting roof does not exceed 50.36 m^3, a summary and calculation of the annual plant water requirement, water storage evaporation, and irrigation water consumption of the planting roof indicate that the total yearly plant water requirement and water storage evaporation are 829.75 m^3, and irrigation water consumption is 278.02 m^3. According to Equation (4), this study case can save irrigation water by 66.49%.

5. Conclusions and discussions

To solve the pain-point problems of traditional planting roofs, we designed a planting roof with compound irrigation and stab-resistant function, which has various advantages compared with other traditional planting roofs. China technical specification for Planting Roof Building Construction (China Institute of Building Standard Design Research, 2013) provides 10 types of standard planted roofs with 8–12 layers of construction. Among them, the simplest planted roof construction has 8 layers, and the bottom-up construction is respectively: reinforced concrete roof slab → 2% slope layer of 30 mm foam concrete at thinnest point → 20 mm 1:3 cement mortar sloping layer → composite waterproofing layer (4 mm ordinary SBS waterproofing roll + 4 mm SBS waterproofing roll with chemical root inhibitor) → geotextile layer (≥300 g/m^2) → 10–20 mm concave-convex drainage and storage slab → 150–300 mm planted soil → plant layer. Calculated according to the house depth of 15 m, the self-weight on the planting roof structural slab is 490 kg/m^2, while the planting roof structure studied in this paper has only five layers, the roof self-weight of 288 kg/m^2, which effectively reduces the construction cost. Some scholars have also studied some newly planting roofs, Pirouz et al. (2023) studied a new multi-purpose self-irrigating green roof with the construction of six layers on the structural roof slabs, where a polystyrene foam layer and a PVC pipe network are installed between the two waterproofing layers, and the PVC pipe network is connected to a multilayered filter and an inverted U-shape outlet, which saves the rainwater to be used for non-potable water, and at the same time is connected to the intake to realize the in-soil irrigation. The planting roof studied in this paper does not require waterproofing roll, stab-resistant layer, PVC pipe networks, and power equipment, and irrigation in the soil is simpler and more convenient compared to it. Cascone (2019) studied a planting roof with the construction of seven layers including waterproofing roll, stab-resistant layer, protective layer, storage and drainage layer, filtration layer, substrate, and vegetation in conjunction with the Mediterranean climatic zone, but there is still the waterproofing roll and the stab-resistant layer, which is still more complex compared to the planting roof studied in this paper. In addition, for planting roof plant irrigation, the traditional planting roof mainly uses tap water or gray water to irrigate roof plants regularly (Ou, 2018; Chowdhury & Abaya, 2018), there are some planting roofs to save water resources, the roof rainwater is transported to the cistern, and then use the pump to send the rainwater to the roof for plant irrigation (Cao et al., 2013; Maftouni & Askari, 2019), these irrigation methods are quite cumbersome, and the equipment investment is huge. Therefore, we laid high-absorbency cinder blocks in the filter layer of the planting roof. After rainwater infiltrates into the filter layer, the cinder blocks can store sufficient water to provide the required water for the growth of roof plants, with a water-saving efficiency of more than 60% and without the need for equipment or building materials such as cisterns, pumps, etc., which largely increase the efficiency of irrigation and help to increase the viability and popularity of the planting roof.

However, the planting roof studied in this paper also has certain shortcomings: in terms of the applicable environment, this planting roof may not be suitable for cold regions because the planting roof has the function of water storage, and the climate, if it is in a cold state for a long period, may lead to the freezing of rainwater stored in the water storage layer, which may not be able to realize its function; in terms of the construction conditions, to ensure the quality of construction, the planting roof should not be constructed and installed in the rainy, snowy, or windy weather of more than five grades (Ministry of Housing and Urban-Rural Development, 2013).

With the acceleration of the urbanization process, urban residents' requirements for living environment are increasing, and planting roofs emerge as the times require. We first analyze the current application status and common problems of planting roofs, then take the problem as the guide, and based on the perspectives of economic cost, construction safety and ecological aesthetics, comprehensively analyze the construction method of the planting roof with compound irrigation and stab-resistant function and its landscape layout from the perspectives of construction, irrigation and landscape, and quantitatively analyze its water-saving capacity in the form of the planting roof. The research results show that:

(1) the number of structural layers on the planting roof structural slab is only five, easy to construct, low economic cost, strong stab-resistance, long service life, and can well overcome shortcomings of the traditional planting roof flexible coiled material.

(2) the planting roof through its own special structure stores rainwater and intelligent irrigation, reducing the management costs of the planting roof and realizing savings in irrigation water up to 66.49%, which largely improves the efficiency of rainwater utilization.

(3) the planting roof landscape design gives full consideration to the local climate and roof leisure function, through the comprehensive use of shrubs, herbs and other plants with each other, to realize three seasons have flowers, and four seasons have scenery. Through artistic techniques, the use of form, color, space and other art elements of plants and landscape stones to create a landscape, achieving harmony and unity between man and nature.

In general, as a bright landscape in the city, planting roofs play an important role in regulating the climate, purifying the air, alleviating urban flooding, etc. In order to further promote the sustainable development of planted roofs, China's national or local formulation and revision of Technical Specifications for Planting Roof (Ministry of Construction, 2007; Ministry of Housing and Urban-Rural Development, 2013), Guangzhou Roof Greening Technical Specification (Guangzhou Market Supervision Bureau, 2019) and other series of normative documents, which put forward specific construction requirements for general planting roofs. Based on those specifications, we have carried out an innovative exploration of the planting roof, which is currently in the initial application stage. With the further popularization of the planting roof, there may be more targeted policies, instructions or regulations in the future to formalize their wider application.

Author contributions

Zhenggen Fan: Conceptualization, supervision, validation, writing – original draft; Ji Liu: Data curation, writing – original draft; Yuqi Fan and Jiasen Pan: Writing – review and editing.

Disclosure statement

The authors declare no competing financial, professional, or personal interests from other parties.

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