 DOI: 10.19601/j.cnki.issn1943 -9903.2018.11.011

Landscape Design of Roof Gardens of Urban Public Buildings

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Abstract This article explores the constraints in the landscape design of roof gardens of public buildings. Based on this, the constituent elements of the roof landscape of public buildings and the cultural ties connecting the elements are studied in detail. Exploring diverse landscape design of roof gardens of public buildings can not only make full use of the building space but also bring more economic, social and ecological benefits.

Key words Public buildings, Roof gardens, Landscape design

1 Introduction

In the process of rapid urbanization in China, the contradiction between green space and urban construction land has become increasingly prominent. The lack of greens pace will lead to a serious of ecological and environmental problems such as the heat island effect. Building a roof garden is a new exploration to resolve this contradiction. It is also an important means to improve the urban ecological landscape by using the "fifth elevation" of the building. Public buildings are buildings that allow people to carry out various public activities, generally including office buildings, commercial buildings, tourist buildings, and scientific, educational, cultural and medical architecture[1]. The roof of a public building generally has a large area, and the property rights are clearly defined and it is easy to implement roof greening on a large scale. It is the most promising place to build a roof garden. The roof garden is a garden built on the roof of a building. In addition to the roof vegetation, it also covers all structures that are not connected to the ground soil, such as terraces, walls, underground garage roofs, and the greening of the buildings, and can be used for sightseeing and rest[1-2]. The most representative prototype of the roof garden began in the 6th century BC. The Babylonian "sky garden", which is known as one of the Seven Wonders of the World, is planted on a stepped platform in the form of a roof garden, and it is one type of roof garden[3]. The most groundbreaking point of view in the roof garden is the "roof landscape" in the "Five Points of New Buildings" proposed by the modern architect Le Corbusier in the 1930s. After a long development process, the roof garden has been turned from privatization to publicization, and related technologies are becoming more and more mature[1,3].

Roof gardens of public buildings can effective use the roof pace of commercial buildings and office buildings for greening, increasing social and ecological benefits without taking up additional urban land. In addition, roof gardens can use the vegetation to regulate extreme temperature changes such as sudden cold and sudden heat to protect the building components[2]. Compared with ordinary roofs, roof gardens can significantly improve the temperature of the top floor, save energy, and reduce the urban heat island effect[2]. In response to the increasingly serious situation of urban waterlogging in China, roof gardens can also use the evapotranspiration of plants to store some rainwater and relive the pressure on the urban drainage pipeline. Therefore, the use of public buildings to build roof gardens not only enhances the urban landscape, but also has the effects of regulating the local climate and improving the quality of the urban ecological environment.

2 Constraints in the landscape design of roof gardens of public buildings

The spatial layout of roof gardens of public buildings is constrained by the building area, building height and structural load. Therefore, their design is more complicated than the ground garden design. At the beginning of the design, the functions of roof gardens of public buildings, such as recreation function, scientific research function and commercial use[2], need to be fully understood, and the following limitations should be considered.

2.1 Roof load The load is an indicator of the weight bearing on the unit area of the roof. It is the guarantee of building safety and the success of the roof landscape[3]. Currently, the roof load of new buildings can reach 700 - 1 000 kg/m^2 or more, enough to carry a garden-lake roof garden, a combination of trees, shrubs and herbs[2]. Old buildings must be subject to additional load testing. Generally, they can carry lawn-type roof gardens (mainly planting lawns and ground cover plants, covering soil thickness of 10 cm or more)[2]. To reduce roof load, new materials, design techniques and concepts can be applied to the roof landscape design. For example, lightweight materials such as plastic and light concrete are used as roof garden structures and landscape sketches. In order to improve the safety factor, the bearing capacity should be arranged reasonably. The design elements such as flower beds, pavilions, tree pools, water features, and rockery stones can be arranged on the main load-bearing structures of buildings to

Received: September 20, 2018 Accepted: Novemer 10, 2018
Supported by Humanities and Social Sciences Research Project for Colleges and Universities in Jiangxi Province (JC161017); Youth Growth Fund of Jiangxi Normal University.
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reduce the burden on the roofs[3].

2.2 Roof waterproofing Roof gardens of public buildings should do a good job in preventing water seepage, preventing plant root puncture and drainage functions in the design. In addition, lightning protection measures, wall constructions, *etc.* [2] should be considered. In the roof landscape design, the treatment of the waterproof layer is the key. The biggest function of the roof waterproofing layer is to prevent water from penetrating into the building. If the safe use and waterproofness of the structure cannot be guaranteed, the roof leakage problem will occur frequently. This not only requires complicated and long maintenance cycle, but also destroys the landscape ecological structure of the entire architecture. Even worse, the floor is prone to cracking and collapsing, affecting the safe use of the buildings[4]. The location of the waterproof layer is generally below the plant. It should be avoided to damage the roof waterproof layer during construction, and avoid the growth of the plant roots to damage the roof waterproof layer.

2.3 Local climate The roofs of public buildings are located high, influenced by natural factors and surrounding structures, and they will form their own unique local climate under certain conditions. Light intensity, wind speed, building shadow, and other factors increase with the height of roofs. The effects of various factors will be gradually magnified after superposed, which determines the design of all available landscapes. Roofs of buildings will receive more solar radiation and greater light intensity than the ground. Therefore, the temperature will be higher than the ground, and the relative humidity is 10% – 20% lower than the ground[5]. This is detrimental to plant growth and can also cause discomfort. Therefore, when plant landscapes are arranged in the open space of roofs, the growth habits of different plants should be considered and the planting locations should be arranged reasonably to ensure that people can get enough shade space even in summer and reduce glare caused by direct sunlight at the same time[5]. Due to the high temperature in summer, the surface of buildings is exposed to strong sunlight, and its surface temperature rises sharply, which can easily cause damage to plants[4]. In winter, the temperature is low, and plants are also susceptible to frostbite or freezing. Therefore, when choosing plants, plants those are drought tolerant and cold tolerant should be selected. Roof management personnel should also take corresponding protective measures for vegetation according to different temperatures[4]. At the same time, wind is one of the factors that influence the landscape design of public buildings' roof gardens. For the roof space, the wind speed is usually 1 to 2 levels greater than the ground, and the wind speed will gradually increase as the altitude increases. When the wind is big, it will have an overturning effect on green plants and landscape facilities. Continuous strong winds are also prone to soil moisture loss, very unfavorable for plant growth[5]. Due to the relatively high winds on roofs and the limited thickness of the soil for plants, the plants grown on roofs should have the characteristics of being wind-resistant and not easily lodging. Besides, effective measures such as windshield or windbreak can be taken to reduce the impact of strong winds on the space environment. In addition, lightweight facilities such as tables and chairs, sun umbrellas, and canopies should also take fixed measures.

2.4 Plant root system Plants are divided into deep-rooted plants and shallow-rooted plants. Plant classification should be carried out prior to plant configuration. Shallow-rooted plants should be selected as much as possible to ensure that the roots of the plants do not affect roofs. If the root system is too deep, it is necessary to consider the root treatment to limit the effect of root expansion on roofs[6].

2.5 Functional requirements The special use of roof gardens should be considered. For commercial buildings, *etc.*, the roof garden landscape requires a strong commercial atmosphere, that is, there is space for events such as parties. The viewing, rest and other needs of crowds should be taken into account. Financial office buildings should consider providing workers with a comfortable outdoor leisure environment and adjusting user emotions[2]. The office crowd also needs a small place for lunch. However, different from the business environment, these places should be quieter and more relaxed[4]. Offices are usually at the upper levels, and the design of landscape should take into the effect of bird's eye view. At the same time, for meeting the functional needs, the safety, fluency, and comfort of roof gardens of public buildings should also be considered.

2.6 Service objects The users' demand for the roof landscape of urban public buildings can be divided into two levels, behavior and spirit, *i. e.* meeting the comfort and safety of walking space and standing space and meeting the needs of spiritual level, inspiring people to create an environment of mutual concern, mutual understanding and mutual tolerance[4]. Venues can be designed according to different service groups. For example, tables, chairs, chess tables, *etc.* are designed for the elderly venues; sand pools, puzzle labyrinths, *etc.* are designed for children's activity venues; and sport venues are designed for young people's venues. More natural elements can be introduced to improve the urban ecosystem, arouse people's attention to nature, and meet the spiritual needs of people's returning to nature.

3 Main design elements of roof gardens of public buildings

Based on the study of limiting factors for the construction of roof gardens of public buildings, micro-topography, water bodies, plants and other gardening elements should also be used to organize the landscape space to achieve better results, and they should be also integrated with the surrounding buildings. At the same time of showing the unique style of roof gardens, they are also coordinated with the main buildings and the surrounding environment.

3.1 Vegetation design Roof gardens of public buildings should reduce their own weight as much as possible on the basis of ensuring the normal growth of plants. They should also subtly coordinate with the surrounding architectural environment[2,5].

Plants are the fundamental to the design of roof gardens. Their weight, growth range of rhizome and canopy, drought tolerance, flood tolerance, water logging tolerance, and the maximum height after maturity are all factors that must be considered when designing roof gardens. The richness of plant configuration is directly constrained by conditions such as microclimate, building load and roof drainage[2]. The upper layer of the plants is combined with tree pools to plant small arbors to define the space for the shade to block the wind. The lower layer is dominated by shrubs and herbaceous plants. The flowering period of the plants is considered to achieve a colorful landscape in four seasons[4]. Second, the environment in roof gardens of public buildings is relatively harsh compared to ground greening, manifested in the aspects such as sunshine intensity, soil thickness, temperature, and wind strength. In order to ensure that plants can grow normally on roofs, plants should be selected according to different environments. For example, small arbors, shrubs and lawns adopted to local environment can be used to construct seasonal changes; and *Ulmus parvifolia*, *Berberis thunbergii*, *Deutzia scabra*, *Dasiphora fruticosa*, *Spiraea blumei*, *Phlox paniculata*, *Hemerocallis fulva*, *Aster novi-belgii* and *Achillea millefolium* are all shallow-rooted plants that are sciophilous and drought-tolerant[2, 5]. According to plant habits and seasons, special attention can be paid to the use of the main landscape trees and the ground cover plants, and low-flowered shrubs for plant matching to achieve better landscape effects. Native species can be used to highlight the local characteristic of the roof garden landscape. At the beginning of the design, effective irrigation method should be selected. Rainwater and reclaimed water can be collected and recharged by means of micro spraying, drip irrigation, and seepage irrigation to save energy[5].

3.2 Water design Waterscape is one of the important ingredients in the design of roof landscape. The ever-changing flow of water will bring infinite vitality to the roof garden and enhance the style of the garden. The optimal position of the water feature is generally determined by taking into the account the main perspective of the garden, the position of the seat and other factors. Due to restrictions by the load-bearing capacity of the building, water should be shallow and the area is not large[3]. The form of expression can be divided into water flow, waterfall, creek and fountain. If the building's load is good, some rockeries or sketches with stacked water can be designed on roof gardens with large area, and fountains can be designed on roofs with small area[3]. Regardless of the size of the body, water feature will bring a vibrant and refreshing experience to the roof garden for its unique and artistic conception. As waterlogging and water shortage coexist in most cities in China, waterscape of roof gardens should consider the recycling and reuse of water resources. The rainfall on roofs can be collected into pools for water supply, grassland irrigation, ground washing and emergency water use to maximize the water-saving function and play the rainwater-storing function of roof gardens.

3.3 Landscape sketch The use of roof space can alleviate the monotony of urban architectural style to a certain extent and enrich the architectural level, making the shape diversified[5]. On the basis of meeting the load requirements, in order to enrich the landscape of roofs, landscape sketches such as pavilions and gallery frames can be designed on roofs[3]. Landscape sketches not only provide users with a place to stop, rest and cool down. They also increase garden usage and enhance the quality of gardens, Plants and landscape sketches will form clear visual contrast in aspects of texture, shape, volume, color, *etc.* The two can complement each other effectively to increase the interest of space and enhance the appreciation of space[6]. Whether landscape sketches are echoing other scenes or self-contained, they can make the roof landscape unique. The integrated use of size, color, style and texture of landscape sketches can make the characteristics and artistry of roof landscape fully displayed.

3.4 Road and site pavement Roads and sites are an important part of the overall composition of roof landscape. They are the veins of roof garden landscape, which are connected with various scenes and have the function of guiding people's sight[3]. Under the premise of meeting the requirements of use, the decorating effect of roads and sites should be emphasized, and it should be combined with the artistic conception of gardening. According to the actual situation, the form, color and material are chosen, and they should try to form a unity with the overall style[1, 3]. In the design, several materials can be used together, so that the landscape of roofs is exquisite and beautiful everywhere. The pavement pattern should be simple and generous. Generally, large-scale pavement and grass is only used as a background. Compared with large-scale pavement, small-scale pavement is more suitable for coordinating landscape elements. In order to maximize the space experience of roof gardens of public buildings, small-scale pavement is a better choice, and it can also reflect the beauty of the gardens. In addition, the pavement should be coordinated with the colors of the vegetation, buildings and landscape sketches. In order to reduce the discomfort of the paving in the sun, the light and color of pavements should be soft. In roof gardens of public buildings, taking into account the load-bearing capacity of buildings, lightweight and beautiful stones and wood that reflects the beauty of nature should be used as flooring materials.

3.5 Color In addition to paying attention to landscape design, roof gardens are also the highlight in the surrounding environment, so they need to have a better overlooking effect. It is necessary to match the plants of each season, and architectural sketches and paving colors can also be used to achieve the desired landscape effect. In terms of plants, the species that have unique landscape effects can be chosen to respond to the impact of the seasons and climate on the landscape, thus achieving the landscape effect with flowers in three seasons and plant scenery in four seasons. Plant dynamics at different seasons should be mastered to facilitate the design according to plant habits, with early flowers in spring, lush green in summer, colorful leaves in autumn and ever green in winter[6]. In terms of architectural sketches, the visual environment can be created by matching contrasting colors, analogous colors

and different color systems. For example, white framing and plants of which colors change with the seasons divide the space into two parts of bright colors and dark colors. In terms of site paving, the color of the precast concrete tiles can also form in harmonious or eye-catching effect on the composition of the entire roof garden. Therefore, roof gardens of public buildings can create a large natural environment or create a virtual natural space according to the characteristics of the buildings themselves. Utilizing the rhythm of color abstraction, hue, chroma and lightness are repeated or matched, interspersed with the combination of shape and line, light and shadow to achieve the desired effects[7].

4 Landscape culture construction of roof gardens of public buildings

The rock in the garden is not only a reflection of the gardening elements, but also a gathering of art creation by the gardeners. The grass, the wood, the flower and the stone in the roof garden of the public building contain culture and emotion. In landscape design, they should be integrated into the original personality culture of the city, so that the context can be passed down. The design that combines local history and culture and local customs is a unique and culturally rich work. China's gardening art pursues the natural spiritual realm, as the highest purpose, trying to achieve the aesthetic effect that although artificially created, there is no trace of axe[8]. The landscape in the garden is entrusted with people's pursuit for quite, refined and bleak life[8]. For example, the roof garden of Suzhou Xinguang Tiandi[9] better integrates the artificial landscape and surrounding natural and human landscape, evoking the memory of southern Chinese riverside town and making the business environment full of emotions and vitality. The roof ecological landscape of Runhua Group[3] is designed with "pen, ink, paper and enamel" as its cultural clues. The pavement and carving of the garden road reflects the calligraphy culture; the water scene is likened to ink, planted with lotus and raised with goldfish; wood chips that are used to pave the road portray the texture of paper; and the wavy stone texture is a metaphor for enamel. In the whole, a roof space full of classical atmosphere is created. Fuzhou Zhongjian Strait Business Plaza[8] is designed with the theme of Chinese characteristics, nature-human integration and full of prosperity, emphasizing relaxed, pleasant, calm, and transcendental natural atmosphere.

5 Conclusions

Roof gardens of public buildings stem from people's thirst for green space and return to nature. They not only relieve the city's heat island effect and the greenhouse effect, but also provide people with an outdoor venue that integrates functions of enjoyment, activities and play. The history, context and life of the city where the building is located should be linked in the design, balancing and blending the roof garden landscape of the building with the old landscape. The roof landscape should align with the surrounding landscape, and the exiting landscape can be utilized to combine humanity and ecology, thus designing a roof landscape that is consistent with the concept of sustainable development, thereby driving the rationalization of structure layout of urban open space, reducing the oppressive feeling generated by the building, and making people closer and more comfortable. Exploring diverse landscape design of roof gardens of public buildings can not only make the building space fully utilized but also bring more economic, social and ecological benefits to people.

References

[1] CHEN Q. Discussion on landscape design of roof garden in Shanghai City——A case of Jinshuiyuan Primary School of Fengxian District[J]. Journal of Anhui Agricultural Sciences, 2016, 44(11): 202 – 203, 221. (in Chinese).

[2] YE KM, LI YY. Analysis on landscape diversity of the roof gardens on commercial building[J]. Architecture & Culture, 2015, 12(12): 188 – 189. (in Chinese).

[3] LIU L, YANG BQ, OU C. Urban "ecological space" ——Discussion on the ecological landscape design of the roof of public buildings[J]. Journal of Chifeng College (Natural Science Edition), 2015, 31(7): 40 – 42. (in Chinese).

[4] CHEN LJ, ZHENG ZC, LAI ZX. Study on the rooftop environmental design of commercial complex——Take Fuchuang Century City of Fuqing City as example[J]. Journal of Yangtze University, 2015, 12(9): 24 – 28, 35. (in Chinese).

[5] DING HX, YAO XZ. Landscape design of roof open space——Take the project of parking building in Xigang District as an example[J]. Journal of Wuhan Institute of Technology, 2017, 16(3): 104 – 107. (in Chinese).

[6] JIANG H, LI L. A preliminary study on the construction of roof garden of underground garage in residential area[J]. Low Temperature Architecture Technology, 2011, 33(3): 24 – 25. (in Chinese).

[7] ZHOU L. Cambridge Center Roof Garden of the United States——The landscape of the visual color[J]. Xiandai Horticulture, 2011, 34(7): 106. (in Chinese).

[8] CHEN P. Research on the construction of rooftop garden landscape culture——A case study of Zhongjian Strait Business Square in Fuzhou[J]. Chinese Horticulture Abstract, 2017, 33(6): 135 – 137,212. (in Chinese).

[9] SUN R. Urban complex rooftop garden landscape design under the background of "experiential" consumption[J]. Housing and Real Estate, 2017, 23(17):55 – 56. (in Chinese).