Effect of Greenbelt Water of Green Roof Index Defined and Planning Measures

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Abstract. Green roof is the source of emission reduction measures for sponge city construction. Green roof rate is the volume capture ratio of annual rainfall of the secondary indicators in sponge city urban planning, one of the city special planning or sponge around urban regulatory detailed planning with clear requirements. Green roof is the sponge as the source of urban rainwater runoff water quality of the construction of water control facilities, while effectively improve urban water environment, in order to maintain the growth of plant needs, green roof greening also to have certain demand. Higher the green roof rate is, the better the annual runoff control rate is, but the increase in water demand is also inevitable. Based on the statistics of the sett value of green roof rate for the existing parts of the city, the related relationship between the green roof rate and the plant watered to demand was putting forward based on the urban green plant water demand. On the sponge city planning, the green roof rate is provided with basic and scientific supporting under the premise of considering the greenbelt water.

1. Introduction

With the continuous promotion of urbanization, the sharp increase in urban population and the concentration of production and living activities made urban buildings and building density continued to increase. And the building roof also became impermeable underside cushion component, its area can achieve the city totalled impermeable area 40-50% [1]. The use of ecological plants to change the nature of roof greening came into being. Reducing urban impermeable area and increasing green area by covering the roof of plants to reduce rainwater runoff.

In the "Sponge City Construction Technical Guide - Low Impact Development Rainwater System Construction", the green roof are included in the source emission reduction measures, and the green roof rate index is proposed. The green roof rate is an important secondary indicator for achieving the annual total runoff control rate in the sponge city planning, and the set value of the planning area is given. The green roof can be used as a decentralized source emission reduction measure to regulate the water quality and quantity of rainwater runoff [2, 3]. Because the roof greening is different from the natural ground, it is different from the ground facilities such as sinking green space, bioretention pool and constructed wetland in the ground. In particular, artificial irrigation is required in arid or semi-arid areas, but freshwater resources in these areas are relatively scarce [4, 5]. If large-scale green roofs are promoted, while the rainwater is released, the plants in the green roof will increase the consumption of urban water.
resources during the non-rainy season, and contradict the current situation of water shortage in most cities in China, while the green roof plants are located in the building. Roofing and watering may result in greater energy consumption. Green roofs bring ecological benefits while also facing challenges [6].

At present, the set of green roof rate mainly considers the decomposition of annual runoff volume capture ratio in the region, the difficulty of building construction and the experience. After the green roof rate is set, there is still a lack of in-depth research on balancing the greening water consumption in the planned area and reducing the urban greening water consumption. This paper gives a correlation analysis of plant water demand and green roof rate through the application status of green roofs in China and the planning of green roofs in sponge city planning. In order to provide basic research and suggestions for optimizing the urban greening water consumption after applying green facilities in the sponge city planning.

2. Green roof and its greening water status

2.1. Green roof application progress

Table 1. The planning requirement of green roof (rate) in some pilot cities of sponge city

| City     | Annual runoff volume capture ratio division | Annual mean precipitation(mm) | Green roof (rate) source |
|----------|-------------------------------------------|------------------------------|--------------------------|
| Beijing  | II, III (75%-85%)                          | 664                          | "Design Code for Rainwater Control and Utilization Engineering" |
| Changde  | III (75%-85%)                              | 1365.5                       | “Special Plan for Sponge City in Changde City (2015-2030)” |
| Nanning  | IV (70%-85%)                               | 1441                         | Nanning City Sponge City Planning and Design Guidelines (released in 2015) |
| Wuhan    | IV (70%-85%)                               | 1260                         | "Guidelines for the Planning and Design of Wuhan Sponge City (Trial)” (released in 2015) |
| Shenzhen | V (60%-85%)                                | 1935                         | "Guidelines for Low Impact Development Rainwater Planning of Shenzhen Guangming New District Construction Project (Trial)” |
A green roof is an engineering measure that lays a natural surface on a building roof (generally a flat roof or a roof with a slope of $\leq 15^\circ$), covers the plants, reduces the impervious area, greens the top of the building, reduces rainwater runoff, and alleviates the urban heat island effect [7, 8]. The green roof are also known as the roof garden, the original landscape use, and with the introduction of the western stormwater management concept, the main functions of the green roof began to change. In the 1960s, the United States proposed the best management measures (BMPs) and Low Impact Development (LID). The green roof began to be promoted as an engineering measure for reducing the source of rainwater. In China, with the development of the city and the demand of urban ecology, research and practice on green roofs have been gradually carried out [9]. Green roofs have been applied in some areas as functional measures for landscape and stormwater runoff reduction. In 2013, China proposed the concept of sponge city construction. Subsequently, the green roof were listed as one of the 17 individual facilities, and the green roof began to be widely used in the construction of sponge cities.

According to the characteristics of geographical location and precipitation, five sponge city pilot cities including Beijing, Wuhan, Changde, Shenzhen and Nanning were selected, and the description and requirements of green roof (rate) in the relevant planning (guideline) of the sponge city were listed. Table 1. Shows the requirements for green roofs in the above-mentioned sponge city pilot city planning. The green roof are recommended as an engineering measure. According to the annual total runoff control rate division and the multi-year average precipitation, the green roof rate requirements and index values are different. However, relevant research studies have found that the green roof rate is mainly based on the annual runoff volume capture ratio, practice research and expert evaluation. In the maintenance regulations, the structure of the green roof and the frequency of plant pruning is mainly explained. The requirements did not explain the method of watering the plants and the source of water in the green roof.

### 2.2. Green roof application progress

Taking Beijing as an example, there were studies[10] on the four experimental sites in Beijing that count the amount of irrigation water in the green roof from June to October, respectively, which were 153.6m$^3$, 50m$^3$, 72.2m$^3$, and 32m$^3$ (area is 1287m$^2$, 700m$^2$, 376m$^2$,206m$^2$), the amount of rainwater interception was added separately, and the average water consumption of each test point can reach 2-4L/(m$^2$·d). In 2017, the green roof area of Beijing has reached more than 2 million square meters [11]. According to the standard, the green water consumption will be 1L/ (m$^2$·d), and the green roof water volume will reach 2000m$^3$/d. This will increase the pressure on Beijing's water supply. According to the Beijing Water Resources Bulletin, the proportion of environmental water in Beijing increased from 2% to 27% in 2002-2015, and the proportion of greening water also increased. Green roof plants are located on the roof of the building and are separated from the natural soil. Irrigation water will require more energy and water. The use of tap water in the building as a water source will definitely increase the pressure of urban water supply. In addition, the use of urban reclaimed water can reduce the pressure on urban water supply and there is a certain amount of energy consumption. It is important to choose the method of watering and management of roof greening.

### 3. Green roof planning considering greening water consumption

#### 3.1. Green roof application progress

3.1.1. Irrigation water volume of roof plants. The vegetation layer is an important part of the green roof. The plants and the soil layer can regulate the water quantity and quality of the storm water runoff. The plants improve the air quality and thus affect the thermal performance of the building [12-13]. The roof of the building is separated from the ground and the natural soil layer. The environment is relatively complex. The structural load, precipitation and drought and flood, plant nutrient supply and wind protection should be considered. Plants should choose plants with strong drought tolerance, strong wind resistance and shallow roots of plants, mainly for evergreen plants, and try to use native plants. On the basis of the above, it is necessary to analyze the water demand of plants. The amount of irrigation water
can be referred to the urban greening water quota. The watering amount per unit area of the green roof can be calculated according to formula (1) [14].

\[ m = \frac{1000H\gamma(\beta_1-\beta_1)/\eta}{\eta} \quad (1) \]

Formula (1): m- Irrigation quota (mm), H- Planned wet depth (m), \( \gamma \)- Soil bulk density (g/cm\(^3\)), \( \eta \)- Water efficiency, 0.3-0.9, Larger values in wet areas and smaller values in dry areas, \( \beta_1, \beta_2 \)- Suitable upper and lower limits of soil moisture content (% by weight).

In the sponge city planning instructions or the corresponding construction design guidelines, the water demand or irrigation water volume of common plants on the green roof is introduced, and the effect of plant water demand on the selection of green roof plants is supplemented.

3.1.2. Water source and irrigation method. The construction of the sponge city reflects the six-character policy of “infiltration, storage, stagnation, cleaning, use, drainage”. The water demand for green roof plants can adopt “collecting-processing-storage-recycling” measures for roof rainwater to improve the utilization of rainwater resources and reduce the pressure of external water supply. Studies have been carried out to water green roof plants in northern Israel using simulated construction grey water and tap water. The results show that plants grow well and are not affected by water sources. Plants that use construction grey water to irrigate green roofs in arid and semi-arid areas are particularly important for their limited use of water resources [15].

Change the structure for water saving. Recently, Korean researchers have proposed a green blue roof. This is a new and improved form of green roof developed by researchers at the Korea Institute of Civil engineering and building technology (KICT). This roof has an additional layer in the green roof design that helps store water in the soil and aquifer. The main advantage of this roof is that it can store more water and help the roof plants to water [16, 17]. Shafique et al. studied the control of rainwater on green roofs and green blue roof, resulting in more green and blue roofs with less water storage and smaller runoff [18]. A green blue roof can store more water, and plants can be used for plant irrigation, building flushing, etc [19].

Choosing the right irrigation method can reduce the amount of greening the roof. The application of water-saving irrigation techniques, such as drip irrigation, sprinkler irrigation, micro-sprinkler irrigation and infiltration irrigation, can have a positive impact on plant growth and landscape effects of green roof. Green roof irrigation can use automatic control technology to improve the efficiency of irrigation water utilization, avoiding the manual control of irrigation system arbitrariness and the amount of watering and watering time can not be accurately controlled. Therefore, it is recommended to apply intelligent and precise automatic control irrigation technology in new roof greening. Meanwhile, the use of automatic control irrigation systems for precise watering is conducive to the full use of water resources and the sustainable development of the city. Experimental data shows that the automatic control irrigation system can save more than 20% of water compared with the manual irrigation system [20]. The method of watering the roof greening can be explained in the corresponding sponge city construction technical manual or guide.

3.1.3. Green roof engineering material optimization. As an ecological technology, green roofs use green building materials as much as possible during the construction process. The application of new materials in green roofs mainly considers the characteristics of light weight, good thermal performance, stable chemical properties, strong water retention capacity, easy construction and environmental protection. According to relevant research, new water-retaining materials such as glass pumice [21], light inorganic matrix (Phosphorus) [22], agricultural rock wool [23], etc. can be applied to the matrix of green roof. Feng Ji et al. [24] studied the application efficiency of water-retaining agent in the cultivation of turfgrass on the roof. After applying the water-retaining agent, it can save 630mm/(hm\(^2\)-a).
3.2. Optimized green roof planning method

In the guide and the sponge city planning in various places, the urban master plan (sponge city special plan) stage proposes the annual runoff volume capture ratio, and the planned green space rate and building density proposed by the detailed planning stage of the city. The sponge city control index system at the implementation level of the plot is mainly composed of single or combined control indicators such as sinking green rate, permeable pavement rate, green roof rate and other storage volume. According to the guidelines and related literature, Figure 1 shows the sponge urban planning hierarchy, planning objectives (indicators) and decomposition method corresponding systems.

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**Figure 1.** Relationship diagram of sponge city planning hierarchy, target and calculation method.

In the sponge city planning, the green roof rate index is mainly explained in the detailed planning level, and is used as the secondary indicator of the annual runoff volume capture ratio to decompose the control volume of the block. Hu Aibing and others [25] studied the overall goal of a sponge city in a certain area of Shenzhen and the process of decomposing it into various construction projects in the new area. Finally, using SWMM model simulation to obtain the green roof coverage ratio and other low-impact development control index values can meet the annual runoff volume capture ratio target. The sponge city evaluation index is established in the control detailed planning index system. The researchers put forward the “index rationality-scientific discussion-expert consultation evaluation-questionnaire survey analysis” process method, and finally get the “guideline-type-index” three-level index system [26].

Combined with 3.1 considerations, sponge urban planning should incorporate plant selection and structure of green roofs into reference factors. It is also possible to combine the conditions of the field to select plants with less water demand, appropriately increase the proportion of recycled water used for greening water, and choose a more water-saving irrigation method under the conditions of green roof rate. Figure 2 shows the green roof rate setting under a combination of factors. At the same time, the water demand, irrigation method and installation cost of common green plants can be added to the detailed planning or construction technical specifications in the form of appendices for reference by design and construction personnel.
4. Conclusion

Whether the green roof is used as a leisure place for “sky garden” or as an engineering measure in the planning and construction of sponge city, it will contribute to the development of urban green ecology and reduce the impact of urban development on local climate and hydrology. Based on the sponge city planning, this paper studies the quantitative value of the green roof from the perspective of the water demand of the green roof.

Research on urban water resources balance based on greening plants on the roof. The following recommendations were made when preparing the green roof rate in the sponge urban planning indicator system:

(1) In the arid/semi-arid areas, when the annual total runoff control rate is zoned in Zone I, the green roof rate should be appropriately reduced, and the utilization rate of unconventional water resources such as rainwater and reclaimed water should be increased. Increase the purified rainwater and reclaimed water as the water source for watering.

(2) In the process of preparing sponge city planning, in order to meet the annual runoff volume capture ratio and only increase the green roof rate, the water-related planning should be systematically planned to make urban water balance planning.

(3) When constructing green roofs in different areas, when planning or guiding, prepare watering or water demand for different plants, and add water-saving irrigation concept in the green roof design process.

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