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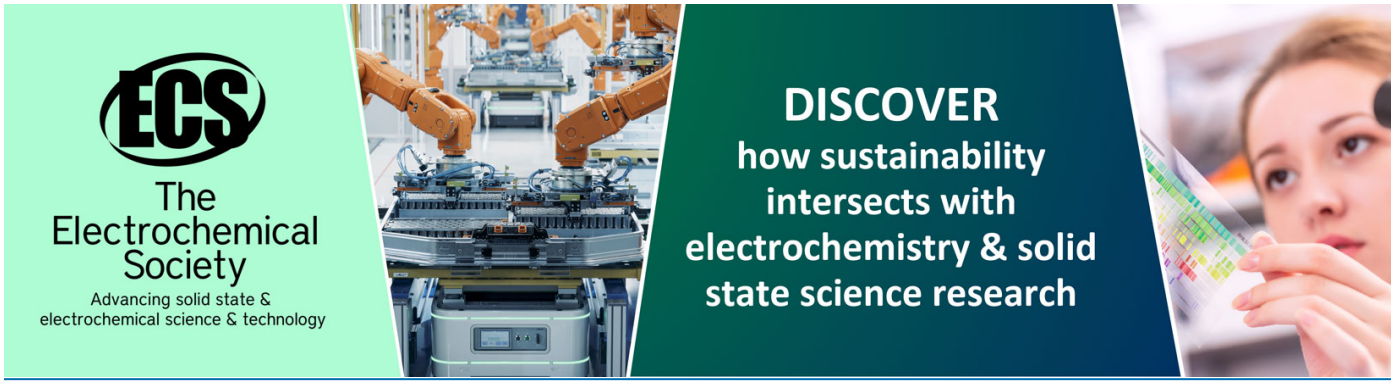

A Discussion on the Construction Ideas of Sponge City in A Green Eco-district

Zhu Wei [1,a*], Li Yumiao [2,b], Wang Chengdan [3,c],

[1] College of Architecture and Urban-Rural Planning, Sichuan Agricultural University, Chengdu, Sichuan, China

[2] College of Architecture and Urban-Rural Planning, Sichuan Agricultural University, Chengdu, Sichuan, China

[3] College of Architecture and Urban-Rural Planning, Sichuan Agricultural University, Chengdu, Sichuan, China

* Corresponding Author: [a*] Email: Zhuwei@sicau.edu.cn

[b] email:lym200126@163.com, wddaxx@163.com

Abstract: With the continuous enhancement of ecological awareness in recent years, sponge city design has become more professional and secure in green eco-district planning. In this context, in order to give full play to the function and advantages of the green eco-district, it is an irresistible trend to advance the progress of the green eco-district planning and accelerate the construction of sponge city. Based on the above situation, first of all, this paper analyzes the significance and value of sponge city from three aspects of ecological benefit, social benefit and economic benefit based on the construction concept of sponge city. Secondly, the planning and design ideas of sponge city construction are analyzed from the perspectives of compliance with principles and proper planning, planning procedures and measures, and the selection of adaptive technologies.

1. Preface

1.1. Green eco-district

The concept of "green eco-district" was jointly proposed by the Ministry of Housing and Urban-Rural Development of the People's Republic of China and the Ministry of Finance and is regarded as the core content of promoting the development of green buildings and eco-cities. The popularization of green buildings has transformed from single green buildings to regional green buildings, and green building technology develops from a single application to comprehensive integration. The green eco-district construction mode based on the large-scale development of green buildings, and the concept of eco-city came into being.

Similar terms abound, but the green building is still in its infancy in China's academic circles. Ma Shijun believed that through the creation of Eco-cities, we could create green, healthy and ecological systems that coordinated the development of man and nature so as to jointly create a green, sustainable and stable urban ecological environment, thereby achieving the coordinated development of man and society, man and nature, city and nature[1]. Shen Qingji explored the ways and directions of realizing low-carbon cities[2]. At the government level, it is necessary to place the establishment of a low-carbon

society at the height of policies. At the economic level, we need to coordinate economic development and carbon emissions. At the individual level, we need to establish the concept of low-carbon life and regulate our behaviors. Through the concerted efforts of various parties, carbon emissions should be reduced to the minimum in order to achieve the construction of low-carbon cities. Qiu Baoxing effectively combined green ecology and low-carbon city development and laid a foundation for establishing green eco-cities by reducing carbon emissions[3].

Green eco-district is defined in the Assessment Standard for Green Eco-District (GB/T51255-2017) as "an urban development zone, functional area and new urban area that are planned, constructed and operated according to the requirements of resource conservation and environmental friendliness in terms of spatial layout, infrastructure, buildings, transportation, industrial supporting facilities and other aspects." Green eco-district introduces the concept of "greening" from the front end of planning, design and land transfer, which may be the development mode of new urban construction in China in the future.

1.2.Sponge city

Sponge city is a new generation of urban stormwater management concept, which means that the city has good flexibility in adapting to environmental changes and coping with natural disasters brought about by rainwater like a sponge. It is also known as a "water-resilient city" [4]. The general international term "sponge city" refers to "low-impact development and construction of the rainwater system." The rainwater system absorbs, stores, seeps and purifies water when it rains and releases and uses the stored water when necessary so as to realize the free migration of rainwater in the city [5]. In order to optimize the city's rainwater drainage system, Sponge City provides a new solution. It has the functions of rainwater storage, utilization and purification, which is also a leading tendency to construct green eco-cities. The construction of the sponge city promotes the development and utilization of urban water resources and effectively limits the destructive effect of urban construction on the environment, which is conducive to the development of green eco-cities. In traditional districts, the rainwater drainage system is composed of pipelines, pumping stations and tank farms. Although it is used to collect and discharge rainwater, there are still problems. There are higher requirements for the layout and construction of drainage pipelines, and the water and soil pollution caused by direct drainage of rainwater also exist. Therefore, the construction of sponge city means to gradually improve the rainwater drainage system, improve its control effect of rainwater runoff, give play to the functions of rainwater purification and storage, and promote the construction of green eco-district.

1.3.Limitations of traditional urban water supply and drainage planning

As for the current situation of the urban rainwater drainage system, first of all, with the urban development, the land occupation scale increases, and the rainwater runoff and its peak value also increase significantly. In case of heavy rain, the drainage capacity will be insufficient, resulting in urban waterlogging. Secondly, due to the strong scouring effect of rainwater, harmful substances in the air, buildings and the ground will be accumulated in the surface runoff and eventually merge into the urban drainage system. However, if the rainwater is discharged directly, it will pollute the water source, harm the soil quality, and destroy the urban water environment. Finally, due to the traditional pavement of urban ground, the impermeable underlying cushion structure is mostly adopted, making it impossible to store and absorb the rainwater effectively. Simultaneously, the evaporation of water on the ground is hindered, and the air on the ground is seriously deficient of water, leading to the dry island effect, which is not conducive to the protection of the urban ecosystem. Based on the analysis of the current situation of the urban rainwater drainage system, it can be seen that the effective use of water resources has not been achieved in urban planning, and urban waterlogging, water pollution, dry island effect and other problems exist, which greatly limits the construction of green eco-district, and is not conducive to the effective implementation of sponge city. Therefore, it is necessary to implement the construction plan of sponge city, promote the development and protection of water resources, improve the urban drainage system, and control the discharge of rain and flood better.

2. Key techniques for building sponge city

To develop sponge city, we should try our best to reduce its adverse impact on the environment, adhere to the principle of ecological optimization and local conditions, and also develop a scientific urban plan to coordinate all aspects of its construction. In addition, green rainwater facilities should be actively developed and applied to make sponge city more capable of self-infiltration, purification and storage of rainwater and flood, improve the construction effect of sponge city, and realize the effective protection of urban ecology. The rainwater runoff should be controlled from the source in a decentralized way, and the technology plays an effective role in controlling environmental pollution and ultimately realize the effective circulation of natural water in the sponge city. The effect of the rainwater control mechanism can be close to that of the source control mode in practical application, and it has the functions of distinguishing rainwater management area and abandoned areas. In the development of green eco-cities, green rainwater facilities play an important role in enhancing the harmonious relationship between the urban environment and contribute to the health of the urban water environment. It meets the development requirements of sponge city and contributes to the cycle control of water resources, and greatly improves the environmental benefits of sponge city. The key techniques for sponge city are as follows.

2.1. Bioretention technology

Due to the good filtration and adsorption effect of the biological matrix, bioretention technology is mainly used for runoff pollution and flow control. When the rainwater flows through the matrix, it will stay there and slowly infiltrate into the ground, which can reduce the rainwater runoff and control the runoff pollution. In the urban environment, bioretention technology has various application forms in parks, squares and both sides of roads, such as green buffer belt, low-elevation greenbelt, and ecological wetland. For example, on municipal roads, a bioretention greenbelt is set on both sides of the road, and drainage holes or curbs are reserved for making the rainwater flow into the bioretention greenbelt. In order to ensure the effect of rainwater retention treatment, the drainage outlet of the road is directly into the bioretention pond, and it should be set between the road and the bioretention pond in height. The bioretention pond is usually a multi-layer structure composed of gravel layer, soil layer and vegetation layer from bottom to top. Moreover, it has a concave depth of 100 to 300 mm, and the necessary structure for water inlet and overflow should be equipped. In addition, we should also effectively investigate the road trend, geological and green conditions, and take it as an important basis for constructing road greenbelt. In particular, it is necessary to make full use of the original green area as the rainwater bioretention greenbelt. The sponge city's precipitation will eventually flow into the ecological wetland through the urban rainwater pipeline system under the effect of multiple retention and subduction. For this reason, it is necessary to rationally plan the area of the ecological wetland, scientifically consider the urban regional precipitation and the water catchment area of pipelines, and ensure the rationality of the setting of ecological wetland.

2.2.Permeable pavement

The main technical approaches to realize the water permeability of pavement are reflected in two aspects: 1) The gap area between materials in the pavement should be expanded to improve the water permeability of the gap; 2) The permeability rate of the pervious material should be accelerated. According to these two kinds of permeable forms, permeable pavement can be divided into three categories as follows:

2.2.1.Permeable underlay pavement with gaps

The water permeability of the gap mainly refers to a gap between the bricks in the paving process of the combination and connection of the pavement bricks, while the gaps are filled with ceramsite, small stones or fine sand. In this type of paving system, the paving material itself is impermeable, relying instead on the bricks' gaps to penetrate the surface rainwater. The typical representative materials are bread brick pavement and grass-planting brick pavement.

2.2.2.Self-permeable underlying pavement

The underlying surface formed by this paving is a complete block, so there is no gap between materials. The pavement material has a structure of pore channels through which water can be permeated. When the rainwater falls on the pavement material, it can infiltrate into the base and soil layer along the pores. When there is no rainfall, the pores, as a channel connecting the soil and air, can be used to permeate and ventil. Typical representative materials are pervious concrete pavement and pervious asphalt pavement.

2.2.3.Composite pavement mode

In order to strengthen the water-permeable capacity of the surface as much as possible, and combining the advantages and disadvantages of self-permeable pavement and permeable pavement with gaps, various types of permeable bricks are developed. These permeable bricks have their structure with pores, and some gaps are left between the bricks in the laying process. At the same time, the advantages of these permeable bricks are complementary. This new type of permeable brick has higher water permeability and can be used for permeable pavements with gaps. Under the double permeable effect, the control effect on the peak value of surface runoff is better, and the advantage is prominent.

However, the above three types of permeable pavement are the same in the pavement's overall structure, with a permeable surface layer, cushion, base and leveling layer and other structures, constituting a complete permeable paving system. In the bottom layer, blind drainage pipes, which are semi-permeable and mainly used for connecting channels of the rainwater pipe network, should also be set up. In this way, the permeable pavement system as a whole constitutes a fully porous structure. However, if the blind pipe is not laid, the lower part of the road surface cannot drain effectively, which will result in a rainwater accumulation effect and affect the control effect of rainwater runoff.

3. Planning and design ideas for building the sponge city

3.1.Following the principle and planning reasonably

In order to give full play to the function of sponge city, relevant designers need to comprehensively consider urban water systems, ecological environment, cultural landscape and other factors, strictly abide by the relevant planning principles, and truly achieve scientific and reasonable planning. At the same time, they should set up the planning concept according to local conditions and work out a systematic and perfect design scheme(Figure 1).

Figure 1 Sponge City Planning and design process

Under the guidance of the urban master plan, the sponge city is planned according to the following steps: 1) to evaluate the overall situation of the local site, including terrain, drainage basin, drainage pattern, soil, geological conditions, natural water body, wetland, vegetation and other background conditions; 2) to delimit urban rainwater drainage basins and determine which green rainwater infrastructure technologies suitable for background conditions can be adopted in each basin; 3) to plan the above measures according to the basin, including the application scope of various green rainwater infrastructure and the applicable neighborhood plots; 4) to determine the planning index value and control the runoff, rainwater and pollutants discharged from inside the site to outside the site.

3.1.1.Attaching importance to the ecological environment and prioritizing nature

To smoothly build a sponge city, we need to make full use of the rain and flood resources. Hence, in building a sponge city, we must focus on protecting the natural environment and paying attention to the balanced development of the ecological environment, and constantly strengthen the restoration and

protection of the original ecological environment, so as to truly realize the harmonious development between human and ecological environment [6]. In addition, since the greenbelt can purify, store and adjust rainwater, designers should make full use of the greenbelt in the construction process, reduce the probability of runoff pollution as much as possible, so as to maximize the recycling utilization rate of rainwater [7], thereby guaranteeing that the city can develop in a positive, stable, healthy and sustainable manner.

3.1.2.Reaching the standards comprehensively and planning uniformly

Under normal circumstances, it is the first step to building a sponge city by accelerating the formulation and improvement of the sponge city's management index system. It has a direct impact on the overall management level and the construction level of the sponge city. Therefore, it is particularly important to develop and improve the index system of sponge city management [8]. First of all, the new concept of sponge city construction should be applied to the overall planning and design of sponge city. The overall planning and design of sponge city should be done from national economy development planning, social and economic development planning, land-use area planning, green space area planning, and urban tourism development planning. Meanwhile, based on the planning of urban space and the principle of developing urban economy, we should focus on increasing the cities' ecological benefits and give full play to the application advantages and values of the concept of sponge city. In this way, it can provide technical support for significantly improving the efficiency and effect of sponge city's overall planning and design.

3.1.3.Emphasizing economic benefits and lowering construction costs

The construction of sponge city is a complex and long-term project, which involves various types of projects and requires many construction funds. Therefore, in the early stage of the construction of sponge city, we should properly manage the funds for the construction of sponge city in the whole life cycle according to the actual needs of the construction of sponge city. In addition, we should scientifically and reasonably analyze and evaluate the benefits of sponge city construction in planning and design, project implementation, evaluation and maintenance. Simultaneously, to ensure the comprehensiveness and rationality of the evaluation results, it is necessary to analyze and evaluate the construction cost and operation cost of sponge city.

3.2.Planning procedures and measures

According to the relevant standards and requirements of sponge city planning, the construction planning procedures involved in sponge city are mainly reflected in the following aspects: first, we should do a good job in the investigation and evaluation of soil conditions, geological conditions, water conditions and other factors. Designers should do relevant research in the early stage. It should be noted that if the design site is a geological environment with potential hazards such as obvious steep slope, collapse, landslide, debris flow, and the soil conditions are expansive soil, self-weight collapsible loess, high degree non-gravity collapsible loess or high-salinity soil, the rainwater infiltration system should not be used. Second, regional and urban rainwater drainage should be well planned. It is necessary to consider the combination form of low-impact development facility systems and the facility scale of each system. It can be determined after technical and economic comparison based on project conditions, rainwater control and utilization objectives, municipal conditions, recyclable water consumption, environmental and sanitation factors. Third, we should define the indexes' values in the planning and reasonably control the sewage discharge.

Under the guidance of the construction planning procedure of sponge city, the construction of sponge city needs to start with the following planning measures: First, priority should be given to the planning and protection of sensitive ecological areas [9]. For areas where construction is restricted, we must make a reasonable plan of the blueprint. At the same time, while improving the utilization rate of rainwater, the secondary pollution of water resources should be avoided to the greatest extent. Second, the urban water system space should be reasonably planned to improve the scientific nature of the regional water

cycle so as to avoid the disorderly development of sponge city in the construction process. Third, surface runoff should be controlled scientifically and rationally. In constructing a sponge city, there is no doubt that the surface runoff coefficient will be increased to some extent, which leads to the general decline of the infiltration capacity of rainwater. Therefore, it is necessary to increase the infiltration facilities, such as infiltration wells and wet ponds.

3.3.Selection of adaptive techniques

The construction of sponge city mainly involves technologies such as seepage technology, backwater technology, water storage technology, water purification technology, water use technology and drainage technology. Therefore, it is particularly important to select appropriate technical facilities flexibly and reasonably. In building a sponge city, water storage technology needs to be used to achieve the purpose of water storage, which is mainly applied in the selection of water storage facilities. The rainwater gardens and ponds can be used to improve the facilities that detain and store rain and flood resources in the sponge city.

In addition, in determining measures for the utilization of stormwater resources, water purification technology should be selected, and the application of water purification technology is mainly reflected in the selection of purification facilities. In the early stages of precipitation, it is necessary to use purification facilities to remove pollutants carried by rainwater effectively. Water storage facilities are then used to store the purified stormwater resources for firefighting and greenbelt watering. In this way, it will help minimize the use of tap water from the city to truly save water resources and improve the utilization rate of water resources(Form1).

Form1 Planning measures for green rainwater infrastructure at different scales

Project	Technical measures	Features
Venue and roof	Green roof	Rainwater reduction and pollution interception on building roofs
	Rainwater collection and storage	Collect rainwater on the roof or the site for storage and utilization
	Initial rainwater abandonment	Source reduction and pollution interception of confluent rainwater runoff on each underlying surface of the site
	Rain garden	Biological retention facilities with landscape functions, with functions such as infiltration and purification
	Ecological landscape storage water body	Set rainwater centralized regulation, storage and purification measures, with both infiltration and reuse functions
Road and square	Road	For the design of municipal roads, a combination of water-permeable paving, sunken green spaces, biological retention ponds, and shallow vegetation trenches can be used
	Plaza / parking	Used for parking lot design and renovation, it can be combined application of water permeable pavement, recessed green space, biological retention pond and other measures
Green space and water	Ecological barge with sunken green space	Mainly use rainwater infiltration
	Ecological river revetment	Adopt the form of ecological river revetment, so that it has various functions such as pollution interception, purification and landscape
	Large water / wetland	Centralized regulation, storage, purification, and reuse of rainwater runoff in a large area

3.3.1.Planning and design of sponge city in ordinary buildings and communities

In ordinary buildings and communities, the overall planning of a sponge city can be designed through low-impact development facilities such as green ecological roofs, rainwater gardens, sunken green spaces, and permeable pavements. The rainwater on the roof can be directly collected and stored, or it can be infiltrated into underground facilities for detention, collection and storage after it enters the site, or the two forms can be combined. At the same time, combined with the urban rainwater pipe network system, the rainwater pipe network can be introduced into the green space and community, and finally, the rainwater will be collected into the rainwater storage facilities, landscape water bodies or wetlands. It can then effectively connect the rainwater collection system, pipe network drainage system and excessive rainwater control system and realize the comprehensive utilization of rainwater.

However, it should be noted that when the amount of water that can be recycled during the average rainfall interval is less than the amount of water that can be collected daily by the roof, the rainwater utilization mode combining the two is preferred. At the same time, urban water resources designed should also be taken into account, and the soil infiltration condition, rainwater demand and water quality requirements of the site proposed in the geological survey report should be referred to. When water quality is highly demanded, ecological facilities should be set up on the ground to purify the rainwater before it penetrates the ground.

When designing the greenbelt as a sunken greenbelt, the pedestrian road should be 80 ~ 100 mm higher than the greenbelt and move towards the greenbelt with a gradient of 0.5% so as to facilitate rainwater collection and be used for the greenbelt to conserve water and reduce irrigation. In the greenbelt, the rainwater inlet higher than the greenbelt but lower than the pedestrian road should be designed to prevent excessive rainwater retained. The remaining rainwater collected should be discharged into municipal stormwater pipes through the stormwater system. When water is included in the community's landscape design, the roof rainwater should be preferentially supplied to the landscape water body. When the outdoor soil allows the stormwater to converge and infiltrate, and there is enough space for infiltration, the rainwater generated by the roof can enter the building. When the rainwater recycling system and reclaimed water collection system are set up in the community planning, the two systems should not be mixed as far as possible.

3.3.2.Planning and design of sponge city in roads and squares

The runoff rainwater on the roads and squares is collected and transferred via the system. Then, it is introduced into the greenbelt around the designed site after being intercepted and purified. It is treated and used by the ecological sponge city construction facilities set in the greenbelt, used for rainwater infiltration, storage and adjustment. According to the terrain characteristics and the surrounding environment, proper forms of facilities should be selected to make it economical, effective and convenient. The hollow square and rainwater garden can be designed preferentially according to the land-use situation around the project.

3.3.3.Planning and design of sponge city in gardens and greenbelts

The construction of the ecological sponge city in the park, the greenbelt and surrounding areas, is the same as the previous two district designs. The rainwater needs to be collected, intercepted and treated, and then introduced into the construction facilities of the ecological sponge city in the greenbelt to consume the runoff rainwater of the greenbelt and the surroundings. It is connected with the municipal rainwater system in the region and the runoff drainage system for disposing of excess rainwater. At the same time, attention should be paid to feasibility and economy, and the natural environment should be used for treatment, such as the construction of wetland parks and the greenbelt with landscape waters.

3.3.4.Planning and design of sponge city in industrial parks

The function of natural infiltration is to reduce the degree of surface runoff and reduce the peak discharge. In the process of building sponge City, the construction planning of the industrial park is quite different from that of ordinary buildings and residential areas. The industrial park mainly consists of hardened

ground and large industrial buildings, with a small area of greenbelts, roads and squares. To build the ecological sponge city as perfectly as possible, first of all, we choose materials with good water permeability to reduce surface runoff and achieve the purpose of infiltration of rainwater to the maximum extent, based on meeting the requirements of outdoor engineering design and relevant standards. Secondly, the permeable pavement should be applied to the applicable carriageway and pedestrian footpath, and the design should be combined with the sunken greenbelt, so that the infiltrated rainwater can flow from the pavement layer to the soil layer. At the same time, the remaining runoff rainwater is discharged to the earth through the road rainwater pipeline. On the one hand, it can improve the infiltration effect of natural landforms. On the other hand, it can give full play to the flood discharge function of the road drainage system.

In developing and constructing industrial parks, the original natural landforms will inevitably be seriously affected. Simultaneously, due to a large number of buildings in the industrial park and the high building density, the appearance of roof rainwater also increases the runoff coefficient of rainwater to some extent. Therefore, when constructing the sponge city, we need to make more effective use of the rainwater sink to store some areas and scientifically and reasonably adjust and control the flow of the flood peak. Meanwhile, in planning the flood control and flood discharge system in the sponge city, we should combine the sink and sand pool to store rainwater, precipitate and purify the impurities in the rainwater and save the land area.

4. Conclusion

To sum up, the acceleration of green eco-district planning is a necessary condition for the realization of environmental protection and green ecological construction. On this basis, if people want to improve the planning effect of the green eco-district fundamentally, they must do a good job in the design of the sponge city. On the one hand, designers should follow the relevant design principles and make a reasonable plan for sponge city. On the other hand, designers also need to develop systematic and perfect planning procedures and measures. In addition, according to the actual needs of sponge city design, appropriate technologies should be chosen. In this way, the quality and efficiency of sponge city design can be maximized so as to play a crucial role in ensuring the scientific and rational planning of the green eco-district.

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