The inspiration of rainwater utilization of foreign sponge campus landscape planning for Beijing

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Abstract. In this article, through selecting the good effects examples of sponge campus construction in the university of Pennsylvania, Salem State University, Arizona State University, State University of New York, and other landscape transformation as the research objects, the paper focuses on the application of sponge city concept in foreign campus landscape planning. It analysis design methods in response to the campus the ecological sustainable public green space design, the rain garden design, roof garden, ecological grass ditch and a series of soil restoration based on the sponge city idea. At the same time, it selects the construction of sponge campus of Beijing Jiaotong University as a comparative study example, in order to explore the potential rainwater utilization and development of sponge campus in China.

1. Introduction

Due to the early appearance of sponge city related technical methods in foreign countries, its application in campus landscape planning research and cases are relatively mature. Such as the University of Maryland, the University of Pennsylvania, Princeton University, the University of California Santa Barbara, Yale University, Arizona State University, Harvard University and other colleges and universities, entrust professional institutions to make Sustainability Water Storm Plan for various campus, and combined with a variety of campus architecture, also combined the Low Impact Development measures with landscape design. Among them, the most famous ones are Tabor Mountain Middle School, Arizona State University Biology Institute, and rainwater garden of Sonoran Desert Landscape Laboratory, the rainwater garden of the beehive library at the University of Worcester in the UK is also an example of sustainable rainwater design in universities[1]. In addition, the rain water pipe strategy of the University of Maine and the rain flood storage and protection design of the University of Mississippi campus are all representative design cases. Taking the Beijing Jiaotong University as an example, this paper analyzes the present situation of the sponge base in the campus, summarizes the current problems of rain water use in the campus, and explores the landscape transformation of the existing sponge basement and the technical measures for the sponge campus. Through collecting rainwater from the roofs, roads and public green space, through the purification of rainwater garden, grass planting ditch, rainwater pipe and so on, the rainwater is drained into the Ming Lake. After storage and purification, rainwater is used as landscaping and greening water in the campus, and a basic plan for comprehensive utilization of campus rainwater is designed.
2. Case study on sponge campus design abroad

2.1. Rain garden landscape at the university of pennsylvania

Ecological campus planning and design at the university of Pennsylvania, low impact development technology of the total area of 17.5 hectares, of which green roof area is 1700 square meters, permeable ground area of 5500 square meters, the rain garden covers an area of 15000 square meters[2]. Shoemaker green covers an area of 2.75 acres, the project is to renew the underutilized land areas where made of unused tennis courts, a few narrow channels and historic war memorial into a green public space for teachers and students to participate in outdoor activities. It consists of a central semi-circular lawn and a large rain garden, its edges made of fine stones breast wall and surrounded by a few elegant winding sidewalks. With the help of the original natural environment conditions, the project made an organic combination with the artificial rainwater garden and other infrastructures to form a functional whole. Through this integrated landscape system, 95% of the rain water in the entire site can be collected, transported, filtered and stored, and then used for irrigation[3]. The project won the 2014 ASLA general design honor award, which set an example for sustainable campus design.

2.2. Salem state university wetland corridor landscape

Salem State University wetland landscape corridor project site was originally an industrial land which much needed governance. According to the site situation and demand, the architects and landscape designers finally designed out a wetland corridor space in campus. The site is located in the central area of the university campus with high use frequency, it integrated soil restoration and rainwater management skillfully, and fully shows their functions and characteristics. The successful construction of the wetland corridor has played an important balancing role between the two seemingly opposites[4]. The design is made up of a slope of open lawn and an 180-foot-long ecological grass gully, and it goes straight to the wetlands, where all the rain runoff from the project is collected. With the interaction of the natural rain and the manual system, the campus is no longer concerned about the water, and the teachers and students are free to enjoy the view of the campus every day. The project is highly innovative, the environment-friendly design and construction technology has been widely recognized by users. It won the 2014 ASLA professional award and the honorary award for comprehensive design.

2.3. Arizona state university institute of biological design landscape

This project is located in Arizona State University bio design institute affiliated green space in the eastern part of Tempe campus, covers an area of 4 acres, won a Arizona first LEED platinum certification award[5]. Through the ingenious and controlled application of hard landscape, the design creates urban biological communities on wasteland with broaden sources of income and reduce expenditure of water resources and introduced new entrances. Its diverse transportation planning, the method which thousands of people interact with the landscape, and how to achieve customers' goals in sustainability and environmental impact are all worthy of reference[6]. The landscape is innovative in a series of ways to reduce environmental impact. Using a vibrant, shady garden instead of the asphalt pavement. The garden uses permeable ground and grows plants with health care function. Make combination of hard landscape sketches and local natural Sonoran desert scene skillfully to provide a comfortable communication space for human. The storm runoff trapped on the roof is channeled into the garden of the holding pond and eventually hides in a permeable granite square. Install the condensate water collection system, collect all the water generated by the building’s HVAC system, and import it into the glass fiber tank buried in the nearby green space, and store it for irrigation green space.

2.4. State university of new york roof garden landscape reconstruction

The Simmons geophysical center of the State University of New York is an institution that studies mathematics, physics and natural geometry[7]. The design needs to create a sustainable environment
with the most advanced technology and create open space suitable for multidisciplinary communication. The rain and flood landscape facilities in the whole project site are arranged in a reasonable and orderly manner, and the water and trees are arranged on the main traffic routes. The design of the water is used as an important landscape element, the pump is used to realize the water cycle, and the technology and aesthetics are integrated together to realize the sustainable ecology of advanced technology. The project uses the roof as a greening base, and roof garden plants the vegetables, spices and flowers that the restaurant needs; besides, there are open leisure square areas and private quiet rest areas for leisure activities and communication.

3. Inspiration from foreign cases
Through the above typical cases of foreign campus landscape planning and rainwater utilization, it can be seen that the important challenge faced by designers nowadays is how to skillfully use the concrete measures of sponge city in campus landscape design, so that it cannot only continue the original design vision, but also meet the new demands of contemporary development. In the construction of sponge campus, there are rules to follow.

3.1. Restoration of abandoned space and brown Land
Designers have reacquainted the importance of traditional campus space landscape aesthetics and the great significance that public space on campus brings to users. They have begun to make use of the good location of campus space for ecological restoration, transforming the abandoned land in the campus, the old industrial area and other space into a public open space focusing on rainwater collection, leisure and landscape aesthetics. By recreating the original abandoned school site, it would restore the energy of its public space.

3.2. Sponge campus concept requires multi-disciplinary cooperation
Campus planners consider and manage sponge campus as a whole concept, integrating planners, architects, hydraulic engineers and landscape designers from multiple disciplines and angles, and covering measures and methods of rainwater collection, storage and utilization. Old campus space reparation and reconstruction is also needed to consider the relationship with the original campus base, so as to coordinate the natural state and human design, optimize the use of the overall best state. The sponge campus is not only the design and optimization for the local campus of campus, but also the concept of nature and large landscape, and the new campus should integrate into the concept of sponge city in the planning of layout.

With the construction and development of colleges and universities in China, sponge campus, low-impact development concept, landscape ecology and so on have been gradually paid attention to. Chinese researchers study on the campus green space is more focused on the perspective of overall planning of campus, campus landscape and space environment design, and the related research of the campus sustainable rainwater landscape system is accompanied by a growing urban waterlogging problems. At present, the development of sponge campus in China is mostly in the theoretical research level, but there are few projects completed and implemented, mainly including: reconstruction of Shengyinyuan in Tsinghua University, reconstruction of Civil Engineering College in Shenzhen University, Jiangsu Urban and Rural Construction Career Academy sponge city demonstration project, Huazhong University of Science and Technology sponge city demonstration project, Tongji University sponge campus reconstruction, ecological engineering of rainwater recovery and utilization in Huairou new campus of Chinese academy of Sciences, Shenyang Jianzhu University sponge campus renovation, Tianjin university new campus landscape planning and North China University of Science and Technology landscape planning and construction in the new campus, etc.
4. The sponge campus landscape planning design measures in Beijing Jiaotong University

4.1. The basement of sponge campus in beijing jiaotong university

Beijing Jiaotong University has made great contribution on rainwater utilization and water saving, which has won the honorary titles of ‘national advanced unit of water conservation’ for 3 times, ‘Beijing advanced unit of water conservation’ for 16 consecutive years. It is the first group of colleges and universities of water treatment and rainwater interception system in Beijing, the first group of pilot universities of water-saving campus in Beijing, and the first group of colleges and universities in Beijing that have passed the acceptance of water-saving zones. The total area of the campus is nearly 1,100 mu, divided into two parts: the main campus and the east campus. The school has nearly 30,000 students, covering an area of 638 thousand square meters and a construction area of 841 thousand square meters. In order to build a water-saving campus, the school has carried out reclaimed water and rainwater utilization at a very early time. The treated reclaimed water and rainwater are used for afforesting irrigation and flushing toilets. As early as 1993, the reclaimed water treatment station was constructed, and the water conservation demonstration project was listed by Beijing government at the same year. After many years running, the annual average water savings were close to 30,000 cubic meters, and a good economic benefit was created. In 2006, the Xueyuan student apartment and its matched reclaimed water treatment station were completed. The apartment use reclaimed water to flush toilets, the annual average water savings were nearly 40,000 cubic meters. In 2011, the newly built student activity center and its matched reclaimed water treatment station were put into use, and its daily treatment capacity reached 280 cubic meters. The treated reclaimed water can meet the greening and cleaning requirements of the main campus.

Since the ‘rainwater interception project’ started in 2005, the school has collected about 200,000 square meters catchment area of rainwater from the west part of teaching area and the west part of family area. It collects reclaimed water about 150 cubic meters per day, and drains the reclaimed water into the Ming lake every day, which has solved the greening water of more than 100,000 square meters greenin the campus site. Thus, more than 250,000 yuan can be saved every year[8]. The advanced methods of the rainwater use in school were introduced at the Beijing water affairs construction conference in 2006, and it was supported by the Beijing municipal government. Micro-reclaimed water treatment measures are applied to No.16 and No.20 student apartments, saving 4,000 cubic meters water and saving 60% water annually. Reclaimed water reuse measures: bath waste water treatment station and reclaimed water treatment station were constructed in 1991, and then ‘bath reclaimed treatment system project’ was put into use. The project was included in the water saving demonstration project in Beijing in 1993, with an average annual water saving of nearly 30,000 cubic meters. With the increase of the number of teachers and students and the increase of the building area, the total water consumption did not increase but remained relatively flat.

4.2. Major existing problems

Beijing Jiaotong University has done some work and achieved some results in the construction of water-saving campus, but it is still far from the goal and requirement of sponge campus construction, which is embodied in the following aspects.

4.2.1. Rainwater collection and infiltration aspect. Due to the early construction of the school, the school has large building density, low green land rate and high impervious paving rate, which is not good for rainwater infiltration. The roads in the campus are mainly cement concrete roads, and occasionally there are paths and garden paths that are hard pavement floors or gravel paving. Most of the roads and squares in the campus use impervious materials which is not good for infiltration and easy to cause rainwater collection and other problems. Due to the traditional municipal drainage model, the waterproof pavement of the site accounts for a large proportion, and the rainwater cannot complete the infiltration, resulting in the runoff of water on the road surface. A large amount of water runoff causes surface pollution, which brings many inconvenience to teachers and students. In addition, no
buildings in campus have considered building roof greening and rainwater collection and utilization facilities. (Figure 1)

![Figure 1](image1.png)

**Figure 1.** Hard pavement is not conducive to infiltration of rainwater.

4.2.2. **Rainwater retention aspect.** Many gardens in the campus are flat or raised hills, such as the raised green area aside by Fanghua garden and Yifu building, which is not conducive to the rainwater collection, so it is difficult to alleviate the phenomenon of surface water accumulation. There is also a lack of rain gardens and bioretention ponds in public green spaces. Some flowers and plants in the campus are potted plants that can be moved at will, most of which only meet the aesthetic function, and the plants have few layers, the plant landscape is relatively monotonous, and the effect of retaining rainwater, soil and water conservation is poor. Therefore, it does not play the role of collecting rainwater and lacks the ability of plants to purify sewage. (Figure 2)

![Figure 2](image2.png)

**Figure 2.** The raised hills and roads aside by Fanghua garden and Yifu building.

4.2.3. **Rainwater purification aspect.** At present, the Ming lake water purification system is relatively perfect in the campus, and there is no artificial wetland purification system. Some of the rainwater collected is used for greening irrigation, flushing toilets and the Ming lake landscape water. In addition, although the campus has rainwater utilization measures, such as the courtyard rain garden in the u-shaped area between the newly built yifu building and the electric building, the landscape effect is poor and the maintenance is poor after the construction, which cannot reach the preset ecological value. After the construction, the construction waste is placed at will, without necessary protective measures. Children directly go down to the rain garden to trample on plants, and the pebbles used for infiltration fall into the collecting pool at will, which affects the original function. The vertical design of green space is not reasonable and the ecological benefit of ornamental grass is low. Many current green areas, such as Siyuan lawn, are mainly ornamental and don’t fully consider the need of rainwater infiltration, and the campus needs a large amount of irrigation water, with low ecological value.

4.3. **Design countermeasures**

Through the case study abroad, combined with the actual situation of school, strengthen the recycling and utilization of campus rainwater. Combining the campus landscape with the technical function of sponge city, which is ‘infiltration, retention, storage, purification, utilization and drainage’, through the reconstruction of buildings, roads and public green space, the surface runoff in the campus can flow into the central Ming lake district in the campus, so as to reduce the surface runoff in rainy days, reduce the rainwater pressure to the underground pipelines in the storm flood peak. At the same time, optimize the landscape effect. Through combining sponge city technology measures and plant configuration, make reconstruction to the public green space, flower ponds and retention ponds in the campus, so as to have coordinated aesthetic feeling on form, material and plant selection. The perfect combination of sponge city technology and art enjoyment realizes the dual meaning of technology and ecology, and tries to create a safe, ecological and pleasant sponge campus landscape environment.
4.3.1. Rainwater garden public green space design. Reduce the topography of Fanghua garden, Jixiu garden, Siyuan lawn and chairman Mao statue green field area which have high vegetation coverage and located in the central area of the school, and construct several rainwater gardens. When rainwater comes, road water and roof drainage can be collected to the rainwater gardens, make rainwater stay, reduce its surface runoff. At the same time, some plants with developed roots, luxuriant stems and leaves, and strong purification ability can be selected to remove harmful substances. Through reasonable design methods, multiple garden sponges are created to achieve good landscape perception and visual enjoyment. (Figure 3)

4.3.2. Green rainwater garden roof design. Choose the suitable buildings on both sides of Yinxing avenue to build roof gardens and design roof greening on the top. When rain comes, absorb and collect some of it. When the rainfall exceeds the maximum amount of rain the roof garden can handle, drainpipes can be used to send excess rainwater to nearest rainwater gardens. Excess rainwater from the roof garden of Siyuan building and Siyuan west building can be collected into the rain garden of Siyuan lawn. The excess rainwater from Siyuan east building and Science hall can be drained to the Ming lake rain collection zone. Rainwater from Hongguoyuan hotel and Yifu teach building can be collected in rainwater garden in Fanghua garden. Rainwater from the seventh teach building can be collected to the chairman Mao statue rainwater garden. (Figure 4)

4.3.3. Road paving design. In view of the problem that all the roads in the campus are hard pavement at present, water-permeable asphalt pavement should be laid on the east-west main roads such as Zhixing avenue, Yinxing avenue and Tianyou avenue. The north-south secondary road and the small path should be laid on the colored permeable concrete and granite lithotripsy, and the terrain should be higher than the surrounding rainwater gardens. When the rain comes, the water on the road can infiltrate on the spot, conserving the lower soil and supplementing the groundwater. The excess rainwater can also be collected into the surrounding rain garden to supplement the water for plants, so as to revitalize the previously soil below the road surface and become the spongy body of the linear road in the campus.

4.3.4. Intelligent detection system and benefit analysis. To build a perfect sponge campus, we need not only the project construction, but also a perfect intelligence testing system. It can use BIM technology to have a scientific prediction and precise calculation of intelligent design, and all kinds of water consumption online monitoring, ranking publication, etc. Through the detection and control on the rainwater gardens, roof gardens and relative facilities, collect data information like rainwater runoff, which is a series of ‘smart+sponge’ approaches, to realize the intelligent water recycling, and introduce the post-use evaluation index system when necessary to track the project, so as to achieve the best sponge campus construction.
Through the sponge restoration and renovation of the campus space, most of the rainwater in the whole site can be collected and used. According to the analysis, the annual average potential of rainwater collected under the most perfect condition is 96,400 cubic meters, which can save 480,000 yuan of water cost per year. Compared with the existing rainwater utilization measures in our school, the annual saving of water is 50,000 cubic meters, a total increase of 46,400 cubic meters. Although a certain amount of financial support is needed for the construction of sponge facilities in the early stage, its economic benefits in the later stage are also considerable. Therefore, it not only greatly reduces the loss of rain water resources, but also realizes the sustainable ecological campus construction of water collection, water storage and water circulation. At the same time, it also creates a landscape environment with aesthetic functions, giving teachers and students a good sense of the environment.

5. Conclusions
As a practical place for teaching and research, university campus should actively promote and utilize new theories and technologies in campus construction. By establishing sponge campus, teachers and students can get closer to nature and feel the ecological environment. At the same time, sponge campus is also a part of urban sponge body, which is also of great significance to the establishment of sponge city. This paper selects several successful abroad cases of sponge campus construction for comparative study in order to find out the countermeasures of sponge campus development in China in the future. By taking the construction of sponge campus of Beijing Jiaotong University as an example, the author tries to realize the infiltration, storage and purification of ground rainwater according to local conditions. The purified rainwater will be discharged into the waters of the central Ming lake, and landscape water will be supplemented if necessary. The quality improved water can also be used for campus greening, car, road and playground cleaning, the excess rainwater can be drained into municipal pipelines. At the same time, the intelligent detection system was added to establish a water circulation system for collecting water, using water and draining water intelligently, so as to improve the utilization rate of campus rainwater resources and realize the construction of sponge campus with sustainable development.

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