Research on the Construction of Sponge Campus from the Perspective of Low Impact Development

——A Case Study of Jiangpu Campus of Nanjing Tech University

Lin Ling[1], Shenzhi Dai[2]

[1] *College of Architecture and Urban Planning, Tongji University, jsdtll2009@163.com*
[2] *College of Architecture and Urban Planning, Tongji University, szdai2606@126.com*

Abstract: The rapid development of cities has caused serious damage to the urban ecological environment and has caused great changes in the global climate. In recent years, sponge city planning and construction have been carried out in many cities. As an important part of the city, the waterlogging problem of universities should also be paid attention to. Taking Jiangpu Campus of Nanjing Tech University as an example, through field investigation, we found that there are 9 locations with serious water accumulation on campus, 4 locations with different water accumulation degree were analyzed and selected. The causes of water accumulation were analyzed by controlling variables (including green space scale, green space density, terrain height difference, permeable pavement area, drainage facilities, etc.). Among them, we selected two indices include green space scale and distribution, using FRAGSTATS3.3 software, to describe the characteristics of green space patch landscape of 4 locations in detail.The analysis shows that the causes of waterlogging in the campus. Based on the study of 6 classical cases in China and abroad. Eight measures for building the campus as a "sponge campus" are put forward from two aspects of construction technology and management, in order to alleviate campus waterlogging, improve water environment quality and increase water recycling.

Keywords: Low Impact Development; campus waterlogging; sponge campus; strategies

Introduction

With the acceleration of urbanization and the expansion of urban scale, extreme weather occurs frequently in the world. At the same time, the change of urban land use pattern leads to the change of hydrological effect and the increase of the proportion of impervious surface, which leads to the continuous increase of urban rainwater runoff and the coexistence of waterlogging and "Thousand Island Effect" in cities. This series of problems are also prominent in our university campuses. Nanjing University of Technology is located in the rainy southern city, and its waterlogging problem is particularly evident in the rainy season. The construction of sponge city is an effective way to maintain a good ecological environment and alleviate urban floods. Therefore, applying the concept of sponge city to the construction of campus and forming "sponge campus" is an important means to solve campus waterlogging and maintain a good ecological environment of campus.

Drainage Status and Existing Problems of Jiangpu Campus of Nanjing University of Technology

1.Campus introduction

Geographic location: Jiangpu Campus of Nanjing University of Technology is located in Jiangpu Street, Pukou District, Nanjing City. It is located at the foot of Laoshan Forest Scenic Area. It faces Puzhu South Road in the south, Yanshan Avenue in the north and Flower Avenue in the west. Pukou District of Nanjing City is located on the North Bank of the Yangtze River in Nanjing City. It is located in the north latitude of 31 degrees 14'-32 degrees 17', east longitude of 118 degrees 20'-119 degrees 13'. It faces the Yangtze River in front, followed by Chu River, Laoshan Mountains in the middle, and hills in the west. There are alluvial continents along the rivers. According to the topographic differences and geomorphological characteristics, four major areas are formed naturally, namely, the polder along the river, the polder along Chu, the mountainous areas, the nearest hills and the distant hills, as shown in Figure 1.

Figure 1 Nanjing University of Technology Campus Plan

Climatic conditions: Jiangpu Campus of Nanjing University of Technology is located in the middle and lower reaches of the Yangtze River. It belongs to the subtropical monsoon climate zone. Rainfall varies greatly between years and seasons, with obvious abundance and drought and uneven distribution of rainfall. According to many years'data and statistics, the average annual rainfall in the whole region is 1102.2 mm, 1778.3 mm in flood year (1991), 465 mm in dry year (1978), 712.1 mm in flood season (May-September), 1324.5 mm in flood season (1991), 248.8 mm in minimum rainfall (1978) and 301.9 mm in maximum daily rainfall. （5 July 2003). The local annual average runoff is about 262 million cubic meters.

Topographic features: Jiangpu Campus of Nanjing University of Technology is located in the hilly area at the foot of Laoshan Mountain. It is an irregular rectangle, about 2200 meters in length from north to South and 920 meters in width from east to west. The terrain is low in the South and high in the north, with an elevation of 10 to 60 meters. The campus is a multi-channel alluvial land separated by many hills, with large fluctuations and scattered land use, as shown in Figure 2.

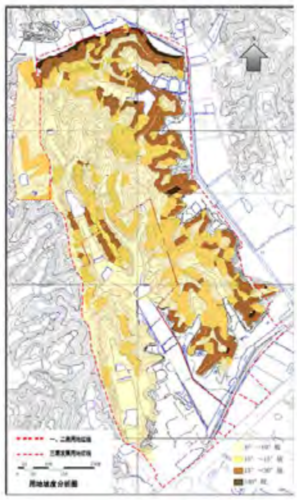

Figure 2-1 Distribution of Surface Runoff System in Jiangpu Campus, Nanjing University of Technology (left)
Figure 2-2 Analysis of Land Slope in Jiangpu Campus of Nanjing University of Technology (right)

2. Current Situation of Drainage in Campus

Research object: During the rainy season in Nanjing, Jiangpu Campus is often affected by rainstorms, resulting in campus waterlogging. The survey selected nine places with serious water accumulation in the campus, which were: (1) the front square of Yifu Library; (2) the entrance of Pujiang Canteen; (3) the South downhill of Dongyuan Canteen; (4) the front of Thick School Building; (5) the main road of the campus; (6) the east side of the school gate; (7) the music platform; (8) the south side of Building A of Pujiang River; and (9) the west side square of Building C of the Zongpujiang River. The distribution of nine places is shown in Fig. 4. According to the average water depth of nine places, the severity of waterlogging in nine places is sorted. The order from heavy to light is the entrance of Pujiang canteen, the South downhill of Dongyuan canteen, the main road of campus, the front of thick school building, music platform, the east side of school gate, the west square of Pujiang C building, the south side of Pujiang A building and the front square of Yifu library, as shown in Figure 3.

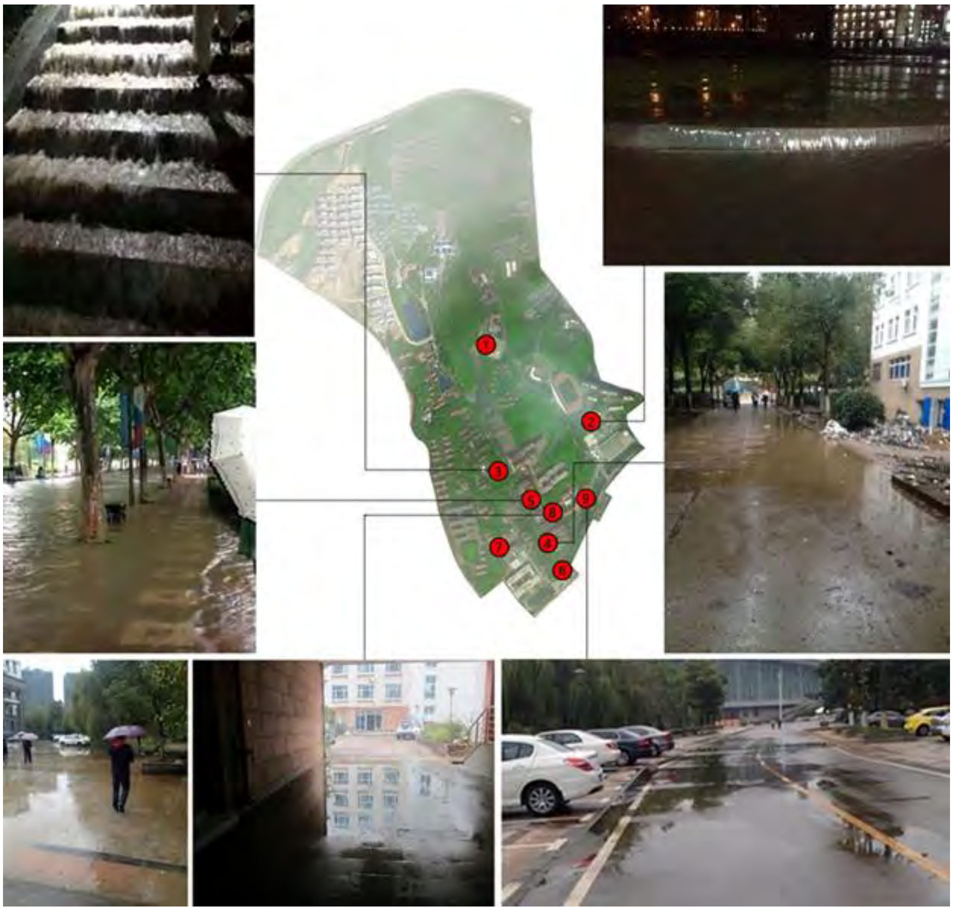

Figure 3 9 Distribution of Severe Points of Water Accumulation

Interpretation of the Current Situation: According to the above survey data, it is preliminarily speculated that the formation of campus waterlogging is mainly related to the degree of green space coverage, and secondly to the height difference within the campus and the area of water area. Therefore, this paper selected four sites with different water accumulation degree to analyze the control variables. The four points selected are: A Music Platform; B East Court basketball court; C Pujiang Canteen Gate; D Houxue Building Gate (see Figure 4). Firstly, the landscape pattern characteristics of green space patches around are described from two aspects: the scale and distribution of green space. Two landscape indices, Class area and Patch Density, are selected (see Table 1). A window with a length of 50 m and a width of 50 m is established. The moving window is calculated by FRAGSTATS3.3 software, and the landscape spatial distribution characteristics of each patch are obtained (Yin Xuewen, 2014).

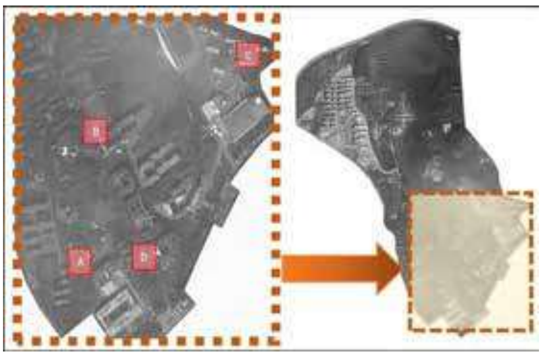

Figure 4 Four Control Variable Analysis Locations

Table 1 Green Space Scale and Distribution Landscape Index

Evaluation content	Name of Landscape Index	Definition of Landscape Index	Implications in this study
The Scale of Green Space	Class area, CA	$CA = \sum_{i=1}^{n} a_{ij}$	Total area of urban green space in a certain range (m²)
Distribution of Green Space	Patch Density, PD	$PD = \frac{n_i}{A}$	Patch Density Reflecting Urban Green Space in a Certain Range
	Landscape Division Index, LDI	$LDI = 1 - \sum_{j=1}^{n} (\frac{a_{ij}}{A})^2$	Reflecting the fragmentation degree of urban green space patches in a certain range, when LDI = 0, it shows that there is only one patch in the area, and the closer LDI approaches to 1, the more fragmented the patches are

(Note: a_{ij} is the area of a certain green patch type, n_i is the number of green patches in a certain range, A is the total area of the landscape.)

(1) Contrast between A Music Station and B Dongyuan East Basketball Court

According to the software analysis, the following four pictures are obtained. From the PD and CA maps of A and B blocks, we can see that the green patch density and patch type area of the two blocks are comparatively similar. But from the field investigation, we can find that the water accumulation in the red area of A block is more serious than that in the red area of B block. By analyzing the similarities and differences between the two plots, it can be found that the height difference between the red area and the green area on the southwest side of Block A is larger, about 1.5 meters, and the pavement in the red area is hard impermeable pavement, while the green area is good permeable grassland. The red area in Block B is permeable and flat, as shown in Fig. 5.

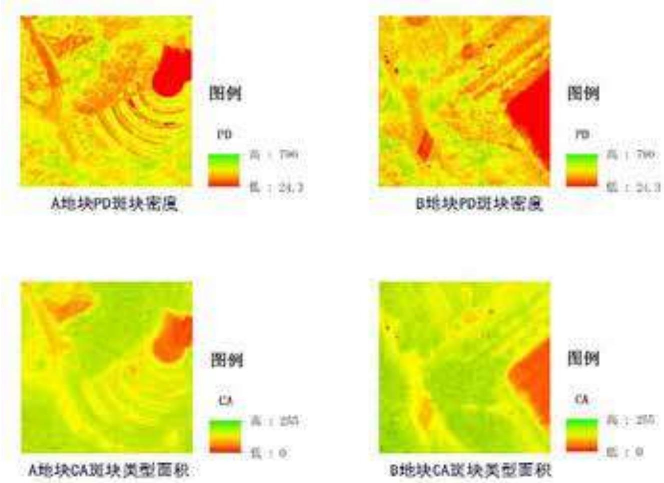

Figure 5 Comparison of Landscape Index of Blocks A and B

Therefore, the analysis shows that Table 2:

Table 2 Comparisons of plot elements and water supply in A and B

Land	**PD**	**CA**	**Height difference**	**Permeable pavement area**	**Drainage ditch**	**Accumulation of water**
A Music Station (Red Area)	Low,	Low,	Large	NO	More	Serious
A Music Station (Green Area)	High	High	Large	Large	Less	Slight
B Dongyuan East Basketball Court (Red Area)	Low,	Low,	Small	Large	More	Slight

Comparing the red area of Block A with the green area, under the same height difference, the factors affecting the water accumulation are the coverage area of green space and the area of permeable pavement; comparing the red area of Block A with the red area of Block B, we can find the factors affecting the water accumulation when the green area is also small. There are height difference and permeable pavement area.

(2) Contrast between A Music Station and the entrance of Pujiang Canteen

According to the software analysis, the following four pictures are obtained. After comparison, the green patch density and patch type area of A plot are higher than those of C plot. Through field investigation, it is found that there are certain height differences in A plot and C plot, even the height difference in A plot is greater than that in C plot, but the water accumulation in C plot is obviously more serious than that in A plot. See Figure 6.

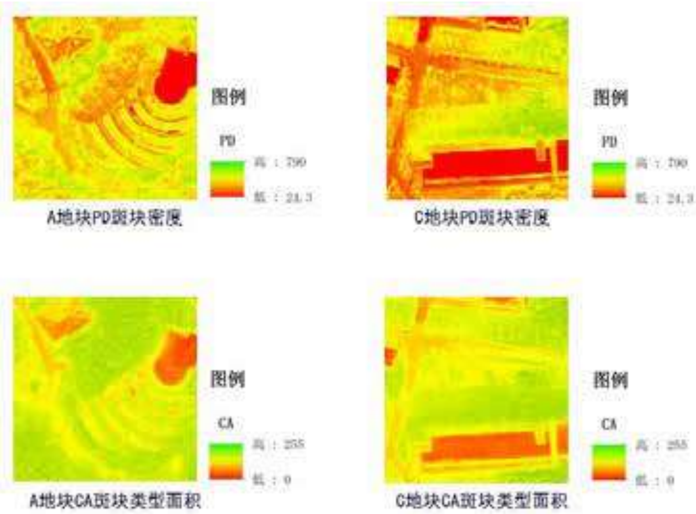

Figure 6 Comparison of Landscape Index of Blocks A and C

Therefore, the analysis shows that table 3:

Table 3 Comparisons of plot elements and water supply in A and C

Land	PD	CA	Height difference	Permeable pavement area	Drainage ditch	Accumulation of water
A Music Station	High	High	Large	Large	Commonly	Slight
C Pujiang Canteen Gate	Low,	Low,	Large	NO	Commonly	Serious

Comparing A plot with C plot as a whole, under the same condition of large height difference, the factors affecting water accumulation in plot A are the coverage area of green space and the area of permeable pavement. Even the plots with large elevation difference are more conducive to rainwater evacuation because they have more green space coverage.

(3) A comparison between the basketball court on the east side of B Dongyuan and the entrance of D Houxue Building

According to the software analysis, the following four pictures are obtained. From the PD and CA maps of Block B and D, we can see that the green patch density and patch type area of the two plots are comparatively similar, but from the field investigation, we can find that the water accumulation phenomenon in Block D is more serious than that in Block B. By analyzing the similarities and differences between the two plots, it can be found that the plots B and D are located in the relatively flat area in the campus, but the plot B is close to more landscape rivers, as shown in Figure 7.

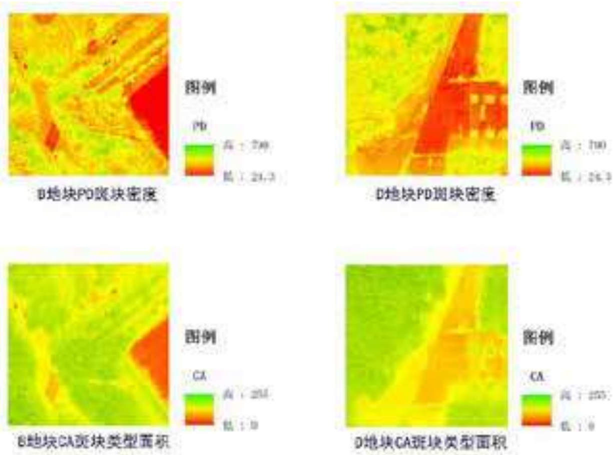

Figure 6 Comparison of Landscape Index of Blocks B and D

Therefore, Table 4 is drawn from the analysis.

Table 4 Comparisons of plot elements and water supply in B and D

Land	PD	CA	Height difference	Permeable pavement area	Drainage ditch	River	Accumulation of water
Near the East Basketball Court of B Dongyuan	Commonly	High	Small	Large	Commonly	Near	Slight
Door of D Houxue Building	Commonly	High	Small	Small	Commonly	Far	Serious

Comparing Block B with Block D as a whole, under the similar conditions of green patch density, patch type area, elevation difference and drainage channel, the factors affecting water accumulation in Block B are the area of permeable pavement and river system.

3. Causes of Campus Waterlogging

After analyzing the current situation of drainage in campus, it is preliminarily concluded that campus waterlogging is closely related to the coverage rate of green space, terrain height difference, permeable pavement area and river course. Further analysis of these four factors can lead to the following reasons for campus waterlogging.

Higher relief: The Jiangpu Campus is built in the aftermath of the National Forest Park Mountains. The whole campus is integrated with the mountain body and built in accordance with the mountain. Therefore, the campus interior is low in the South and high in the north. It is separated by many hills into multiple impacting areas. The land is scattered and the height difference is large. In rainstorms or continuous rainstorms, the rainwater flows rapidly to low-lying areas under the guidance of gravity, resulting in the accumulation of rainwater at low places and the formation of campus waterlogging. At the same time, in the process of water flow, small waterfalls will appear on the slopes. It has seriously affected the travel of teachers and students.

High impervious pavement rate in some areas: Jiangpu Campus covers a large area with dense road network and more vehicles. It needs more parking space. Most of the parking lots in the current campus are impervious pavement. At the same time, the school provides more venues for teachers and students, and also for hard impermeable pavement. The large proportion of impervious pavement in the campus has greatly affected the infiltration of rainwater, resulting in many water accumulation in the campus, as shown in Figure 8.

Figure 8 Water accumulation in impervious pavement

utting off bends and straightening up rivers to weaken the links of "stagnation": The natural river course is meandering and winding. The meandering bank can effectively reduce the speed of flow. With the natural grassland revetment, the impact of water stays in the river course increases the permeability of water. In the construction of Jiangpu Campus, many rivers are straight landscape rivers. Straight rivers seem to be able to drain rainwater quickly, but in fact, rainwater will be accumulated in the lowest place after passing through the rivers quickly, forming a campus waterlogging. Most of the landscaped riverbanks in the campus are artificial hard ones, which not only increase the beauty of the campus, but also reduce the infiltration of water and increase the drainage pressure of the riverway in rainy season.

The water system is dispersed and its circulation is not strong: Jiangpu Campus takes "landscape campus" as its design concept and plans a large number of rivers (see Figure 11 for details). These water bodies form a certain water network structure on the plan, but more of them are blocked in the middle, forming the characteristics of water system dispersion, affecting the flow of water, so when rainwater floods, it will form a serious phenomenon of local water accumulation in the campus, as shown in Figure 9.

Figure 9. Distribution of water system in Campus

Drainage ditches are covered to prevent rainwater seepage: Walking in the campus, we can often see fallen leaves, food bags, express bags and other garbage piled up in the drainage ditches. As a result, when the rainstorm comes, the drainage ditches can not fully play their role, which leads to flooding of the road surface and hindering the travel of teachers and students.

Case analysis and experience summary at home and abroad

1.Case Study of Foreign Countries

In recent years, low impact development (LID) has been effectively used and promoted in the United States. Many famous universities and professional institutions have cooperated to formulate the rainwater management project plan for each school, and ingeniously combine campus landscape design with low impact development technology. The University of Pennsylvania and Yale have worked out sustainable campus rainwater management plans; the Massachusetts Institute of Technology of Harvard University has built ecological rainwater landscape in the process of campus renovation; and the University of Maryland has carried out experimental studies on campus. The practice of low-impact development technology in American universities is mostly to transform the environment after land development, so as to improve the quality of the environment and ecological benefits and form a sustainable ecological landscape on the basis of not destroying the existing concurrent work.

Sunolun Landscape Laboratory： Underwood Family Sonoran Landscape Laboratory, also known as "Home under the Tree", is located in Tucson, AZ USA, See Figure 10.

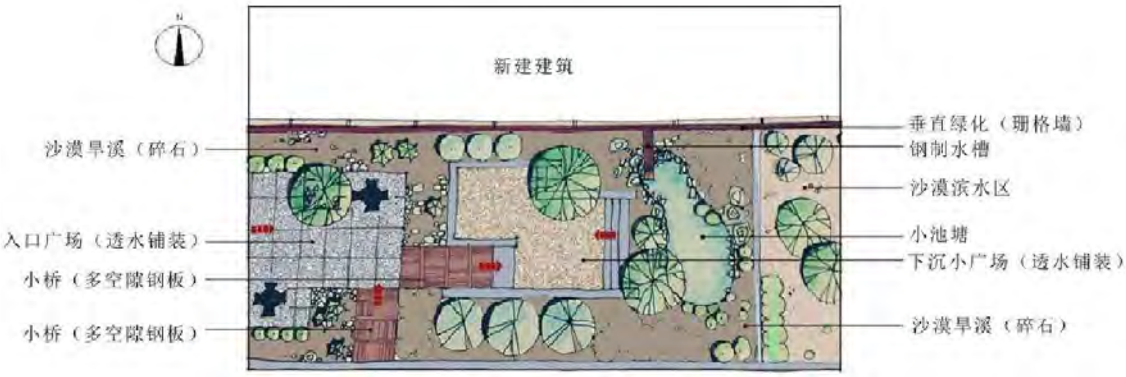

Figure 10 Plane of Suloren Landscape Laboratory

Sunolun Landscape Laboratory fully embodies the concept of sustainable development. Its greatest feature is the collection of rainwater and the recycling of water resources. Through a series of low-impact development facilities, the laboratory has slowed down the speed of rainwater runoff, fully recycled rainwater resources and reduced waterlogging.

Central Plaza, Southwest Residential Area, MIT： The Massachusetts Institute of Technology Southwest Residential District Central Plaza Renovation Project was designed by Stephen Stimson Landscape Design Firm of the United States. The original monotonous and dilapidated square was designed and renovated, and a humanized sustainable open space was created. A visual rainwater system consisting of rainwater conveyor belts and rainwater gardens was constructed, which reduced the impervious pavement rate of the site from 70% to 40%. The coverage of natural vegetation and permeable pavement increased from 30% to 60%, as shown in Figure 11.

Figure 11 Rainwater system plan of site

In the design, the North-South long green corridor symbolizes the Connecticut River, which is the main channel for collecting and transmitting rainwater from surrounding squares and roofs. The corridor links the blocks of green space between buildings, symbolizes the pasture and farmland in the valley, and is also the main place for rainwater purification, infiltration and teachers'activities. The north-south rainwater transmission bandwidth is 1-1.5 meters, consisting of stone strips, metal plates and plants, and equipped with a certain number of log seats for teachers and students to use, as shown in Figure 12.

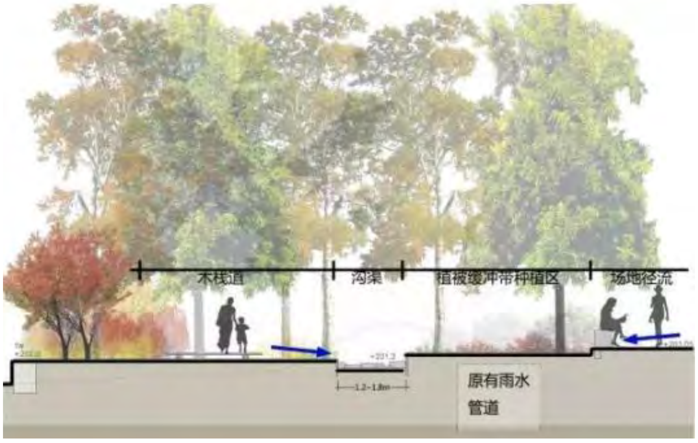

Figure 12 Cross-section of rainwater transport belt

Figure 13 General Plane of the Institute of Biology, Arizona State University

ASU Institute of Biological Design: ASU Biodesign Institute, located in Tempe, Arizona, USA, covers an area of about 16188 square meters. In order to create a sustainable development space, rainwater harvesting facilities were set up in each site to realize the collection and utilization of rainwater resources. Rainwater collection of the project is mainly embodied in rainwater garden, rainwater retention area and permeable material pavement. Through these facilities, water resources are recycled, as shown in Figure 13.

2. Domestic Case Analysis

At present, the construction of sponge campuses in China lags behind the developed countries slightly, mainly in the application of technology, standards, policies and regulations and the overall awareness of co-management. In recent years, the construction of sponge campuses with low impact development has been paid more and more attention in our universities. Tsinghua University, Duke University of Kunshan, Tongji University, Beiyang Campus of Tianjin University, Hunan Agricultural University, Shenyang Architectural University and other universities have carried out the construction and research of rainwater control and utilization projects.

Shengyin College of Tsinghua University: Shengyin College is located in the west of the southern section of the traditional central axis of the auditorium of Tsinghua University. It is one of the modern classroom housing groups of Tsinghua University. With the reconstruction and construction of the school, the surrounding terrain has been constantly raised, and it has gradually become a low-lying area. Every rainstorm will cause serious campus waterlogging.

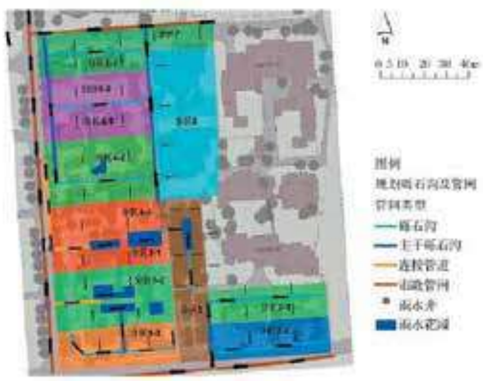

Figure 14 Sewerage Zone of Shengyin Courtyard

In the renovation of Shengyin College, the historical style of its architectural heritage was maintained, and the low-impact development technology facilities and landscape construction were integrated to achieve the collection and utilization of rainwater resources and effectively alleviate the problem of campus waterlogging. Rainfall management facilities in Shengyin Hospital include rainwater garden, dry pool, gravel ditch, grass ditch and so on. See Figure 14.

Duke University of Kunshan: Duke University of Kunshan is located in Yangcheng Lake Science Park, Kunshan City, Jiangsu Province. Its campus covers an area of 1,200 mu (about 130,000 mu). In 2016, Duke University became the first LEED green campus in China to be certified by the American Green Building Commission. Its ecological landscape design and highly hydroelastic "sponge campus" feature are the international leading certification. One of the key elements (Zeng Ying, 2017).

The design of the project combines the characteristics of the space demand of campus users and the change of the water quantity of the central landscape lake, and integrates the analysis of time, space and water level. The central landscape lake will be built as the center of collecting and managing rainwater systematically. Through collecting rainwater from the roof and square of the campus, the original campus will be greened on the West side. The zone is transformed into an ecological park with a series of purified pools connected to the Central Lake, forming a "living water" system circulating and reciprocating in the campus, as shown in Figure 15.

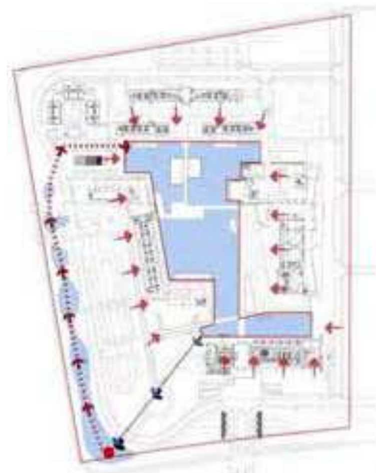

Figure 15 The "Live Water" System of Duke University in Kunshan

In the transformation of Duke University, unlike other universities, the design defines the submergable and non-submergable areas. It describes the elasticity of the sponge campus as allowing the departmental areas to be submerged, but this "submergable" scope and state are controlled within the design scope, as shown in Figure 16.

Figure 16. Different relationships between landscape platforms and water surfaces

Hunan Agricultural University: Hunan Agricultural University is located in Furong District, Changsha City. Its campus covers an area of 2.27 square kilometers. The design of the "Red Axis" landscape in its campus uses the invisible water storage system model. Instead of setting up obvious engineering facilities on the surface, it combines water saving, water storage and other measures with the green space construction and landscape construction of the campus.

Hunan Agricultural University put forward its water storage model based on the current situation of massive waste of energy and resources. The characteristics of this model are to build a series of rainwater utilization facilities by using the accumulation of hard materials such as waste bricks, sandy pebbles and cement blocks, to maximize rainwater storage, to supplement the water retention of groundwater and soil, to improve the growth conditions of plants, to save and adequately water resources, and to reduce them. The pressure of light Rainstorm on drainage pipeline network will build sponge campus.

Figure 17 General Plane of "Red Axis" Landscape Design of Hunan Agricultural University

3. Summary of Case Experience

Adapt measures to local conditions and retain local characteristics: During the renovation of Sunolun Landscape Laboratory, the unique desert landscape was preserved, and many native plants, such as butterfly rattan and mutton tree, were used. These functional elements and social elements were skillfully combined to form a unique and innovative "small sponge" city, which is a demonstration site in the arid and barren southwestern region of the United States.

Analyse the rainwater and flood, study the site sufficiently: The renovation of Shengyin College of Tsinghua University is based on the division of rainwater gathering areas in the site, and then the direction of drainage pressure in each area is analyzed. Finally, the corresponding low-impact development facilities are selected according to the flow of each area, and the implementation location is determined according to the layout of the green landscape. Therefore, a full analysis of the current situation of the plot is the necessary measure for the construction of sponge campus under the concept of low impact.

Recycling and utilizing rainwater in combination with landscape: The Sunorom Landscape Laboratory also has a relatively complete system of reclaimed water in buildings. Designers collect rainwater from roofs, condensate from air conditioners and reclaimed water from automatic water dispensers in buildings through a water tank with a total capacity of 11,600 gallons placed in buildings to meet the needs of inadequate water supply in the site. At the same time, the water can also be diverted to a small pond simulating the desert dry stream by using a steel tank, which can increase the water level and salinity of the small pond and realize the water cycle of the site.

The MIT Square Renovation Project also uses north-south rainwater conveyor belts to collect rainwater runoff and roof rainwater from the site and reuse them after purification of the sunken rainwater garden.

Designers at ASU Biological Design Research Institute set up small gravel-covered basins in the site as reservoirs for rainwater collection.

The renovation of Shengyin College of Tsinghua University integrates the rainwater management facilities with the historical landscape environment, carries out reasonable vertical design, increases the infiltration capacity of the surface, effectively controls the rainwater runoff at the source, and uses the green landscape to treat, recycle and reuse rainwater.

Constructing rainwater recycling system combined with waterscape can not only create a systematic and ecological campus landscape, reduce the phenomenon of water accumulation in the campus, but also greatly save the irrigation water in the campus.

Increase permeability and use permeable pavement : In the design process of Sunolun Landscape Laboratory, many low-impact development technologies were introduced. Permeable pavement was used extensively to increase the infiltration and purification of rainwater. The Massachusetts Institute of Technology (MIT) square renovation increased the permeable pavement rate by 30%, greatly increased the infiltration of rainwater during the rainy season, and reduced surface runoff. Similarly, in the project of ASU Institute of Biological Design, a large number of permeable pavement materials are used to increase the infiltration of rainwater so that groundwater can be recharged and water resources can be conserved.

Optimizing green space and increasing rainwater treatment: Through the analysis of the above six cases and the sponge campus construction of other universities at home and abroad, it is found that green landscape plays an extremely important role in the construction of sponge campus. Its role runs through the whole system, covering the source, middle and end, as shown in Table 5.

Table 5 Landscape Rainwater Disposal Measures for Green Space

Control process	Name	Measures	Function
Source	Roof Garden	Engineering measures for greening roofs, roofs or balconies of buildings or structures	Reducing peak runoff and total rainfall runoff
	Rain garden	Engineering measures for planting shrubs, flowers and plants in low-lying areas, using the biochemical and physical characteristics of plants, bacteria and soil to purify and store the total amount and quality of water in landscape	Purify Rainwater, Increase Evaporation, Blue and Green Space Conversion Place
	Permeable pavement	Engineering measures for the use of pervious materials or engineering practices as engineering measures for the treatment of pervious materials	Rainfall Infiltration Rate Improvement
	Concave green space	A concave green space 50-150 mm below the surrounding hard pavement	Rainwater harvesting, groundwater recharge, blue-green space conversion site
	Landscape tree array	Matrix planting of humidity-tolerant and Saline-Alkali-Tolerant trees at a certain distance to form a characteristic landscape space	Alleviating heat island effect and increasing rainwater infiltration rate
Middle	grassed swales	Landscape Surface Channel Drainage System for Planting Vegetation	Reducing surface runoff velocity and increasing rainwater infiltration
	Gravel grooves	Landscape surface ditch drainage system filled with gravel	Increase rainwater infiltration and purify water quality
End	Wetland	Natural or artificially formed swamps and shallow water areas with stationary or flowing water bodies can provide habitats for birds and fish.	Purify water and precipitate toxic substances
	Landscape water body	Natural or artificially constructed landscapes with water elements, such as concave pools, concave sculptures, dry streams, etc.	Stormwater storage

Divide the area and make sure whether it is submerged or not: When the campus encounters continuous heavy rainfall for many days, even if there is a good water infiltration system and enough river water system to accommodate water, it will cause water accumulation in some areas and form campus waterlogging. At this time, through the division and positioning of the campus area, it is necessary to determine which areas can be submerged and which areas can never be submerged, so as to accommodate rainwater to a greater extent, so that the places with transportation, distribution and other functions in the campus are not affected by waterlogging.

Technical Measures for the Construction of "Sponge Campus" in Jiangpu Campus of Nanjing University of Technology

To build "sponge campus", we must apply the six-character concept of sponge city - infiltration, stagnation, storage, net, use and arrangement to the construction of campus. Based on the investigation and analysis of the current situation of Nanjing University of Technology, combined with the experience of domestic and foreign cases, this paper tries to put forward corresponding measures for the construction of "sponge campus" in Jiangpu Campus of Nanjing University of Technology from the perspective of six-character concept.

1. Iinfiltration

Green Roof： Green roof has the function of saving energy and reducing emission. It can collect a lot of rainwater in rainy season, control roof runoff, and reduce the pollution of runoff, so as to facilitate the recovery and utilization of rainwater. The southern part of Jiangpu Campus of Nanjing University of Technology is relatively dense, so reducing roof runoff is one of the important tasks of building sponge campus, as shown in Figure 18.

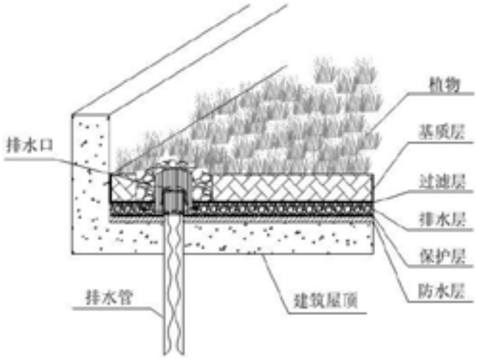

Figure 18 Green Roof Profile

For flat-roofed buildings, when building green roofs, it is necessary to ensure that the roof load, waterproof performance and other indicators meet the construction standards; for sloping roofs, the requirement for building green roofs is that the roof slope should not be greater than 15 degrees. At the same time, green roofs are divided into two types: simple roof and garden roof. The design indicators of the two types of roofs are different, as shown in Table 6.

Table 6 Suggested Indicators for Green Roofs

Form	Greening Roof Area/Total Roof Area	Greening Planting Area/Greening Roof Area	Paved garden pavement area/green roof area	Landscape Art Area/Greening Roof Area	Matrix depth
Simple	⩾80%	⩾90%	——	——	～ 150mm
Garden	⩾60%	⩾85%	⩽12%	⩽3%	⩾ 600mm

Permeable pavement: Permeable pavement has the functions of seepage, stagnation and storage, which can temporarily store a small amount of rainwater. Its main function is to promote the infiltration of rainwater to supplement groundwater and reduce the water volume and speed of surface runoff. In this paper, the analysis of the current situation of Jiangpu Campus shows that most of the water-logged areas in the campus are impervious pavement, such as parking lot, distribution plaza, etc. Therefore, it can be considered to use pervious pavement to update and improve it, as shown in Figure 19.

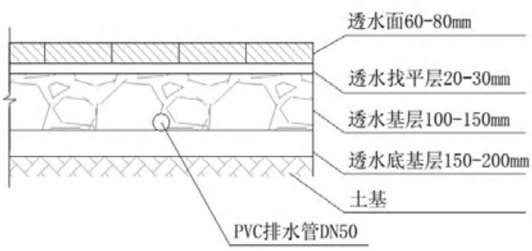

Figure 19 Diagram of Permeable Pavement Section

Natural revetment: From the analysis of the present situation of Jiangpu Campus, we can see that many of the campus landscape rivers have adopted the design of artificial hard revetment, which gives people a beautiful feeling from the visual effect. But when facing the rainstorm, these hard revetments will only increase the flow rate of rainwater and aggravate the phenomenon of water accumulation in low terrain. Therefore, in the construction of "sponge campus" in Jiangpu Campus, we should Restoring the original natural revetment of the river system and increasing the infiltration of water in the river course, at the same time, the original ecological characteristics of the original Jiangpu Campus conform to the theme of its "landscape campus".

2. Stagnation

Concave green space： The concave green space has the natural seepage ability, and can use its concave terrain to block the surface runoff of rainwater, and to a certain extent can store rainwater. The concave green space can be widely used in the reconstruction of campus. It has the advantages of low construction complexity, low construction cost and saving irrigation water. At the same time, the concave depth of concave green space should be determined according to the drowning resistance of plants and the permeability of soil, generally 100-200 mm. In the construction of sponge campus in Jiangpu Campus of Nanjing University of Technology, the corresponding concave green space should be constructed in the low-lying areas according to the topographic characteristics of the campus itself, so as to increase the process of rainwater "retention", as shown in Figure 20.

Figure 20: Concave green space profile

Biological Retention Land: Biodetention is a facility for storing, infiltrating and purifying rainwater through plant, soil and microbial systems in low-lying areas. It includes not only rainwater gardens, but also biological detention zones, high flower beds, ecological tree pools and so on. There are a large number of forest areas and low-lying terrain in the northern part of Jiangpu Campus. The construction of biological retention areas in these areas can not only make rainwater retained, collected and purified to a certain extent, but also make rational and efficient use of rainwater to attract teachers and students. In the construction of biological detention areas, the catchment areas with serious pollution need to be treated and discharged, while the roof runoff and rainwater can be directly connected by rainwater pipelines.

In the analysis of the present situation, we know that the waterlogging of the main road in Jiangpu Campus is serious, so we can construct biological detention land in the green belt on both sides of the road. At the same time, when the slope of the road is more than 1%, we need to set up a weir/platform to slow down the flow rate and increase the water permeability. Leakage prevention treatment is needed near the roadbed to prevent the impact on the stability of the roadbed.

Abandoning straight and bending: In the analysis of the current situation, more water bodies in Jiangpu Campus are linear. When the rainstorm comes, the rainwater quickly passes through the river channel and then accumulates at the lowest point, forming a campus waterlogging. Therefore, in the construction of "sponge campus" in Jiangpu Campus, we should abandon the straight river to bend where the waterlogging is serious, and reduce the flow velocity of the water body through the curved river, so as to achieve the effect of "stagnation".

3. Storage

Reservoir: The function of regulating and storing pond is to collect, regulate, save and purify rainwater. It is an intermittent water landscape. It can temporarily collect rainwater and then discharge it slowly according to need. Reservoir pond can lighten the burden of drainage pipe to a certain extent, at the same time, it can increase the water landscape of campus, and create a good hydrophilic environment for teachers and students. When water storage ponds are laid out in Jiangpu Campus, the original catchment depression in the site can be used to increase the value of recreational use combined with recreational and recreational venues, as shown in Figure 21.

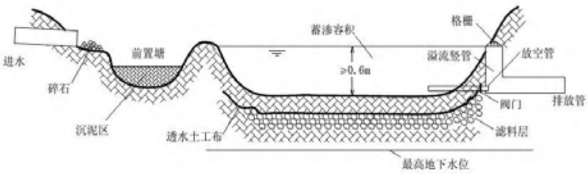

Figure 21 Section Diagram of Reservoir Reservoir

Constructed wetlands: Constructed wetland is a surface water body constructed artificially and operated artificially. It is generally composed of intake, pre-pond, swamp area, outflow pool, overflow pipe, revetment slope, etc. When the constructed wetland is laid out, the mixed plant planting method can not only increase the diversity of campus organisms, but also help to improve the permeability and purification rate, so as to maintain the stability of campus water circulation system, as shown in Figure 22.

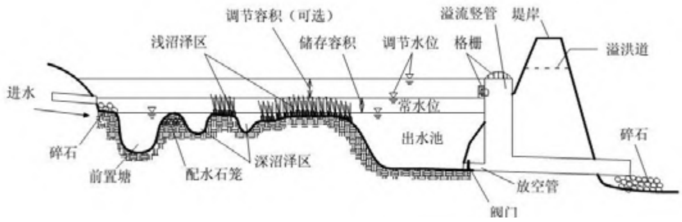

Figure 22 Profile of constructed wetlands

4. Net and Useful

Rainwater treatment and reuse system: After the seepage, stagnation and storage of rainwater, the collected rainwater should be treated and reused. Combined with the facilities of rainwater garden and reservoir mentioned above, the rainwater purified can be used as irrigation water for vegetation, miscellaneous water for teachers and students, emergency water and fire fighting water, so that the rainwater collected can flow. When conditions permit, small-scale rain water purification facilities can be built to produce drinking water up to standard for use by teachers and students in schools.

5. Row

Grass planting ditch: Grass planting ditch refers to the landscape facilities planted in ditches to control flow, transport rainwater and improve water quality. On both sides of the road and around the parking lot square in Jiangpu Campus, the corresponding grass planting ditches can be arranged in parallel with the green space, so as to ensure that the campus ecological environment is not affected, and the rainwater can be drained smoothly. At the same time, pebbles can be set on both sides of the slope of the paper straw ditch, which can slow down the runoff and also reduce the erosion of the slope by rainwater.

Arid stream: Dry stream is a kind of facility to simulate natural streams. It has high flexibility. The streambed has a winding linear distribution. It has no permanent water body. It is usually in the rainy season and dry season. The construction of Arid stream can prevent the soil from being directly washed away by rainwater and reduce soil erosion. At the same time, the combination of layout with campus green space can increase the richness and hierarchy of campus landscape. In the construction of sponge campus in Jiangpu Campus, it can be arranged at the core landscape nodes, such as the side of Junzi Lake, the central landscape belt and Yiqing Tongji Lake.

Measures for the Construction and Management of Sponge Campus in Jiangpu Campus of Nanjing University of Technology

The previous chapter elaborated how to build "sponge campus" under the concept of low-impact development at the technical level. Through the investigation and research of the current situation, it is found that not enough technical means can be adopted to build "sponge campus" well, and the construction of "sponge" city can not be separated from efficient and effective management. Therefore, this paper also puts forward several management measures, as follows:

1. Overall coordination and overall development

Campus as a relatively independent system in the city, is also an important part of the city, so its internal changes often affect the changes of the surrounding and even the whole city. Therefore, in the construction of "sponge campus", we need to consider the construction of the whole city's sponge city as a whole, in order to ensure the coordinated development between the campus and the city.

2. Distribution and recycling of rain and sewage

When rainwater is discharged, the rainwater and sewage should be diverted and treated directly into the sewage pipe, while rainwater can be collected and reused after purification. Therefore, in the construction of sponge campus in Jiangpu Campus, we should strictly implement the rainwater and sewage diversion system.

3. Optimizing water body to ensure water quality

The current situation of water pollution in Jiangpu Campus is serious. Serious pollution has led to the slowdown of water flow rate and the reduction or even disappearance of self-purification ability. Therefore, regular cleaning of water body is necessary to ensure the water quality. At the same time, suitable microorganisms and aquatic animals and plants can be selected and cultivated in the water body to construct a perfect natural ecosystem and water microcirculation system.

4. Zoning and Strict Control

In the "Technical Guidelines for Sponge City Construction - Construction of Rainwater System for Low Impact Development", five regions are divided into five areas to be controlled by indices. Because the terrain of Jiangpu Campus is quite different, and there are differences in the form of building density in different functional areas, the construction of sponge campuses in Jiangpu Campus should also be divided into corresponding zones. The zoning should be carried out from the beginning of the current situation investigation. In the optimizing construction stage, the appropriate facilities should be selected, and which parts of the zones can be controlled. What is submerged in the enclosure must not be submerged. At the same time, it is clear which areas have the most serious waterlogging, so that runoff can be strictly controlled by means of on-line monitoring.

5. Strengthen management and timely maintenance

Investigation shows that more drainage ditches in the campus are covered by leaves and garbage, which affects the infiltration of rainwater. With the development of campus construction, the campus environment is changing constantly. The problem of long-term use of drainage ditches and the old rainwater facilities can not adapt to the changes of the environment are becoming increasingly prominent. Therefore, the construction of sponge campus must strengthen management, timely cleaning of rubbish in rainwater circulation system, and regular maintenance, renewal and repair of drainage facilities.

6. Resource Bearing and Supply-Demand Balance

The purpose of building "Sponge Campus" is to promote the coordinated and balanced development of the campus and water resources, and to realize the optimization of functions while protecting the campus environment. The campus drainage system is planned and constructed according to the number and scale of school development in a certain period of time. In recent years, with the vigorous development of education in China, the expansion of campus enrollment has aggravated the burden of drainage facilities on campus, resulting in waterlogging and other problems. For example, the Central Landscape Department of Jiangpu Campus has developed a large number of departments of the New College of green space construction, resulting in a serious reduction in green space area. Therefore, it is necessary and sufficient to expand the staff and construct the campus under the conditions of resource supply.

Summary

The construction of "Sponge Campus" is based on the existing water system and within the affordable environment, taking scientific measures to carry out in a suitable intensity and manner. The current situation of Jiangpu Campus not only has the problem of waterlogging, but also ignores the "resource" of rainwater. In this paper, the drainage status of Jiangpu Campus of Nanjing University of Technology has been fully investigated and analyzed, and combined with the domestic and foreign cases of "sponge campus" construction, the construction method of "sponge campus" in Jiangpu Campus under low-impact development has been put forward. However, the construction methods mentioned in this paper are relatively general, and only stay at the macro level of what areas can be built. Therefore, it needs further research and textual research on how to improve and improve each existing facility in the campus.

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