RAINWATER UTILIZATION OF GREEN STREETS IN THE SUSTAINABLE CITY

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Abstract- Rainwater utilization is important in dealing with urban water shortages and flooding, and for improving the urban environment. The world has given it a lot of attention and has seen some positive results. Some Chinese cities have also begun to focus on rainwater utilization, and have developed some momentum, but there are still problems in rainwater utilization, including a lack of knowledge and insufficient input. With the Ministry of Housing and Urban-Rural Department releasing Technology guide for construction of sponge City, more and more researches have been done. As a landscape architecture designer, we can use roads as cavernous to collect rainwater, which is especially mentioned in the guide. The paper is aimed to analysis some examples and to have some suggestions of this situation. In this article, some green streets in Lijiang, and in Jiaxing will be used as cases to explain why there were no urban waterlogging in these places, and also introducing some examples in America and Europe. According to these cases, I will summarize green streets' origin, development process and some successful practices, finally put forward some design strategies and mode of Green Street for nowadays, such as rain gardens, plant fence and so on. Therefore, green streets' rainwater utilization are urgently needed in order to make the city more sustainable. However, rainwater utilization is a highly dynamic, complex and multifunctional process, only technical methods are not enough. We also need to increase awareness of rainwater utilization and some related laws to support it.

Key words- Landscape architecture, green streets, rainwater utilization

I. INTRODUCTION

A. Backgrounds

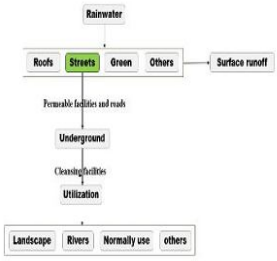
With the Ministry of Housing and Urban-Rural Department releasing Technology guide for construction of sponge City recently, rainwater utilization, once again arouses widespread concern in society. According to the guide, streets are regarded as important cavernous to collect and use rainwater. In our cities, more than 1/3 of the city public system are streets. The data from 2011 even showed that at least 40% urban land was used for road development and construction [1]. The US Environmental Protection Agency once made an experiment, which showed when the impervious area of the earth up to 75% or more, 55% of the rainfall runoff would form while only 15% of rainfall infiltration in the built-up areas of the developed cities (storm water) [2]. Meanwhile, the data from the US Green Street monitoring showed that the construction of rainwater infiltration garden green streets can manage 75% to 80% of the surface rainwater runoff under rainfall intensity surrounding normal form, while its maximum design capacity to withstand the rainfall intensity in the region once in a century but cost is only US-style traditional engineering storm water best management practices 1/4 system (Rain gardens) [3]. In this context, if we can use city streets as a cavernous to absorb and store rainwater, the streets may play an important role in solving the rainwater problem of the cities.

In traditional urban streets design, green quantity is usually not enough, as well as road permeability is poor. And we generally make the green elevation higher than the road elevation, use the paving stone to stock the roads, which makes the water flow on the roads instead of being absorbed by the green. During the heavy rain, the streets become the final collection of rainwater. In this case, if the drainage system is not ready, it will cause urban inland inundation easily.

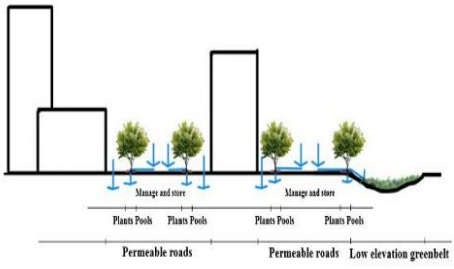
From pic 1, we can get the information that streent is very important to collect rainwater, and it can manage water like pic 2.

B. Concepts

,Mcharg is the first one to put forward the concept of



Pic 1, how rainwater goes after falling(drawn by author)

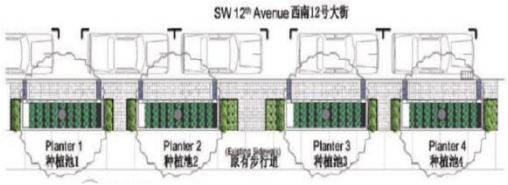


Pic 2, the management of rainwater by green streets(drawn by author)

combining natural and artificial drainage management system in 1971, considering the rainwater and the development of the buildings and sites as a whole,

taking the natural way to reduce the negative influence of urbanization on river and stream, intercepting sewer of rainwater, making it directly into natural systems. Now green streets usually means the form of the combination of street rainwater management and street landscape construction, according to the natural water cycle [4]. What is more, there is still a kind of generalized understanding, which further extended the concept to the scope of the rainwater landscape facilities rainwater management, it means make the street building rainwater management with streets landscape construction, street traffic system together manage the rainwater in streets [5].

In China, studies on urban rainwater harvesting and utilization started relatively late. Some cities have been carrying out rainwater utilization projects, but most of them are in the stage of exploration and demonstration by focusing on the development of technologies and approaches for rainwater harvesting [6].



Pic 3 the plan view of SW 12th Avenue Stormwater (Coming from Website)

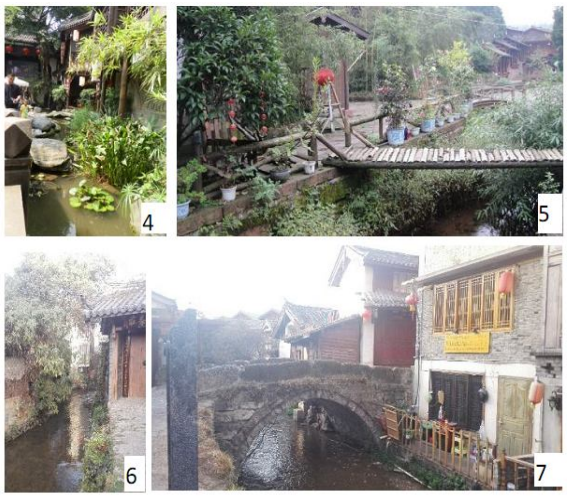
Due to lack of awareness of the roles of rainwater harvesting in reducing runoff volume to mitigate waterlogging problems, many cities hope to build high standard of drainage system to prevent and mitigate waterlogging disasters, although practices have proven that only relying on urban drainage system cannot fundamentally solve the urban waterlogging problems.

According to this, I decided to make an introduction of practices in China and abroad, so that to make people be familiar with green streets more professional. The main objectives of this research are to find some suggestions to solve rainwater utilization from green streets by analyzing some examples.

II. CURRENT PRACTICES OF GREEN STREETS

A. Researches and Practices in aboard

Nowadays, there have been at least 40 countries and regions doing the research and practice of storm water management and utilization. In most areas of North America and Europe, storm water management measures and techniques are named Best Management Practices (BMP) [6]. The Woodlands Practice——Texas (Woodland) of the town planning project—— is the first beginning of this concept, which is accomplished by McHarg and WMRT [7]. Ever since then, America and Europe began a series of practices about green street projects. The first real green street was constructed in Prince George County, Maryland (Prince George's County, Maryland) Somerset residential area in 1990. After that, green streets was approached popularized in the United States.



Pic 4 Jinli in Chengdu, Pic 5 Shangli in Yaan, Pic 6,7 Lijiang in Yunnan (by author)

The project in Portland is an excellent example of rainwater utilization. Portland is in Oregon, which lies in the northwest of the United States, the east of the Pacific. Due to the ocean, Portland is warm and humid in winter, while hot and dry in summer. In general, Portland's annual rainfall reaches to 1029.5mm, among them from November to April is the rainy season, during these months the rainfall up to 80% of the whole year. In this scene, how to deal with the situation of rain in emissions and penetration becomes a very important problem for us landscape designer. In this project, the designers used four planting rain pools (Pic 3) to collect and diffuse the rain water in nearly 780m^2 place. What most impressed us is the two seemingly ordinary pools. When the rain falls, the rain water in the catchment area of 1.44 square kilometers inflows through the roads to the pools, which the sizes are 2 meters wide, 15 meters long. When the soil water seepage flowing inside pool speed reaches to per hour 7.6 cm and the pool of water depth of 17.8cm, it reaches the limit of absorbing water by plants and soil. After that, the pools are not able to continue to collect rainwater, the extra water will flow into the second plant unit through the gravel based on small dam. As the same as the fourth plant unit. When the fourth plant unit is saturated, excess water will flow into the current urban drainage system. Thanks to this kind of plant units in the streets, the rainwater of the whole year in the block, which up to 8500m^3, can be eco-management through this system [8].

Europe has also carried out a series of green streets' practices. Such as sustainable urban drainage system in Britain, which was formed by the chain consisting of the precautions, source, site, regional controls and managements. Besides, they recommend planning policies "in the future use of sustainable urban planning and development and construction drainage systems concepts and technologies to reduce the flood

risk." [6]; the German government formed a perfect union water act and some related state laws and regulations to guide and regulate the sustainable use of rainwater. In practice, many sidewalks and pedestrian streets in the cities used permeable brick laying. Until 2010, 90% of the national urban roads had transformed into different forms of permeable ground [9]. In addition, they also had a major practice characteristics in rain gardens, storm water square, green roofs and so on. Potsdamer Plaza Germany storm water management is a successful example of German urban rainwater utilization.

B. Researches and Practices in China

1) Practices in ancient China

In China, many traditional towns had got the wisdom of green streets before hundreds of years. For instance, Lijiang, Ya'an, Hangzhou and so on (Pic 4, 5, 6, 7).

The width of the streets are coordinated with the width of the river in Lijiang. The width of linear river system in Lijiang are mostly 2-3m, to the widest, it can reach to 5-6m (main channels), which is adjacent to the main streets. With the roads' level gradually reducing, the river tributaries also gradually narrows, while the narrowest point can be only a few tens of centimeters (lateral canal of alleys). The width of the alleys are decided by the water and the street, especially are often associated with the water of river canal. In this context, the streets not only work as the link of the ordinary transports, but also a container of water when rain comes. This kind of spaces' texture is traditional by the water street. It does the same work as the green streets do. The same designs also exist in Ya'an, Hangzhou and so on.

2) Practices in nowadays

Although green streets started late in China, the present practice projects are also not enough, but with the rainwater issues get more and more attention of the government and the society in recent years, the amount of green streets' projects and researches keeps increasing [10].

Jiaxing is a good example of green streets (Pic 8,9,10). Because of the pollution of the storm water runoff and the negative effects from confluence overflow, the government did landscape water facilities' researches and demonstrated projects in Jiaxing city road, green road and residential area, combining with the state water special "river urban storm runoff pollution control and ecological use key technology research and demonstration project". In this practice, the designers used the rain gardens, vegetation shallow grooves, the rain ponds, technology measures such as the ecological floating island and so on, to strand and purify the runoff water through roads and river green belts. According to the statistics of precipitation in Jiaxing, the project realized the expected target: total annual rainwater runoff pollutants (SS) reduction rate is not less than 40%, the storm runoff discharge total reduction rate is not less than 30%.

III. THE DESIGN OF GREEN STREETS

Why does our urban cities always have this problem? In the most streets' design, green quantity is not enough in generally, the roads' permeability is poor and the green' elevation is mostly higher than the roads' elevation, while



Pic 8,9,10 practices in Jiaxing (coming from website)

the streets are closed by the stone edging. With these measures, rainwater could not be absorbed by green in time or drained to pavement when the green is saturated with water during heavy rain. Which means, roads become a gathering place for the ultimate urban rainwater. If the city's drainage system is not perfect, it is easy to lead to urban waterlogging. In this process, streets become one of the cradles about urban rainwater issues. So if we started to regulate urban storm water issues from streets, make the rain water a cycle by nature, it will greatly reduce the subsequent works, such as the works of drainage systems.

A. The design principles of Green Streets

1) Function

Keeping the traffic and walkers safety must be the first thing of streets, which is the basic function. Besides this, we add the ecological regulation mechanism, such as LID (Low Impact Development) and urban stormwater [11], to benefit its function most by combining function and ecological science.

2) Materials

When we design, we should use seepy materials as much as possible, to make the water permeate easily, in this way to let the streets manage the water naturally. At the same time, we should increase the use of new technologies and new materials, especially the recyclable materials and clean energies, in order to reduce the cost to maintain later.

3) Plants

It is very important to use green and soil together to absorb and deal with the rainwater, so we have to be carefully to choose plants: firstly, native plants should be the best choice, as they are more adapt to the soil, and they would not due to ecological invasion; secondly, we should choose the drought-enduring plants which also can be flooding-tolerant for a short time, which means the plant can use less water during dry weather, and suffer through the flood period; at last, we should consider the plants which root systems are rich, to guarantee less soil and water loss [12]. In addition to this, landscape effect should be considered at the same time, in order to make a beautiful street landscape.

4) Landscape

As streets are important public space in our dairy life,

we must take the landscape effect into consideration, cannot ignore human's feelings. In material, color and plant choosing, we should combine function, ecology and landscape together, to make the streets have ecological effect and also be suitable for people to use.

B. Different Kinds of Green Streets

1) Low elevation greenbelt

Low elevation greenbelt is an efficient way to collecting rainwater, it reduces the elevation of green space to form a concave. Beijing once ha an experiment of the relationship between the green space height and the quantity of infiltration in 1990-1991, the outcome showed that if the green's level was lower than the surrounding roads, its infiltration quantity would be 3 ~ 4 times higher than the road's. Now I will divide it into two kinds of forms to analyze as follows:

i. the linear low elevation greenbelt

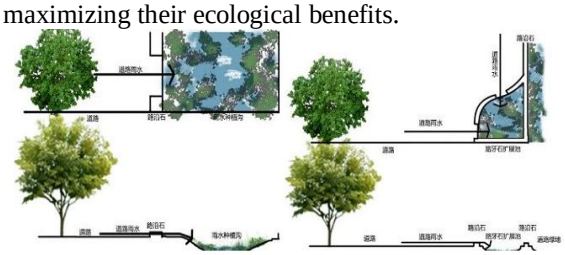
Linear low elevation greenbelt is generally divided into rain planting ditch, rain grow pool and stone edging extension pool [4].Rain planting ditch is a form of the recessed greenbelt, as what picture 4 shows. The groove can be plat or bottom, collocating with landscape plants of water resistant. The section is narrow, both sides are inclined or vertical upward slopes. What is different from rain green pool is that the pool has an inerratic shape. Stone edging extension pool is also a kind of linear under similar as rain planting ditch, it is usually a landscape area in the stone edging and its expanding area, as picture 5 shows. But compare with the rain planting ditch, it has shallow depth.

All these kinds of pools are commonly used in linear road. Combining landscape effects and water loving of humans, they can become good walking streets, to create roads of a slow traffic state, such as in urban road branch and residential areas; at the same time, we usually collect rainwater by rain plant ditches and rain grow pools which are set by the main urban expressway and urban general.

ii. the planar low elevation greenbelt

Planar low elevation greenbelt contains rainwater infiltration garden and rain gardens. They are used more widely, because they can be changed with sites' conditions.

In the roads, they are generally applied to green space with a certain width, or the urban traffic island. We should make these green spaces work efficiently, not just confining to function of beautification, but also maximizing their ecological benefits.



Pic 11,12 different kinds of low elevation greenbelt (drawn by author)

In this context, handling of urban rainwater will play a very good role of "source". However, most rain gardens in China do not really function in rainwater collection and utilization, they are more of a landscape form, rather than the use of ecological methods.

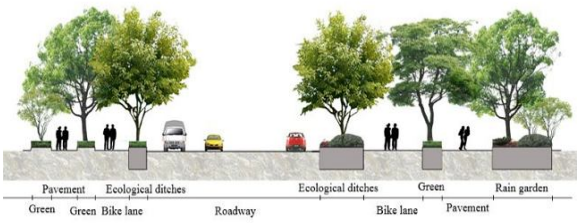
2) The materials

The most basic and important element of roads is the rigid pavement. In the design of roads, first of all, to make the rain flow into the green, the level of roads should be higher than that of nearby green spaces; then the materials of roads should have a basic function of waterproof, prevent slippery, wear-resisting and so on. Some researches show that the permeability of concrete pavement water capacity equivalent to twice of the ordinary water storage facilities, while the ability of reducing runoff of permeable pavement can reach to 40% ~ 90%, which is about 10% higher than that of no collection measures, and the ability of reducing flood peak is 20% ~ 80% [13]. With this materials, it can reduce the pressure of facilities of traditional storm water management. Otherwise, the congestion of this materials should also be considered when using it to design pavements, which requires designers having the knowledge of methods to roads and the basic surroundings of roads, and where is easy to block, so as to have an appropriate selection of materials.

C. The point of Green Streets

1) Urban planning

We should consider green streets during urban planning, combining urban rainwater system. In addition, we could use policy guidance and mandatory to control rainwater gradient, such as Beijing, which issued the policy that "each 10000m^2 construction must make sure 500 m^3 space to store water".



Pic 13 the mode of green streets (drawn by author)

Because rainwater gradient is a complex process which need multi-sector work together, the government can choose a department to be a leader, to make urban planning, municipal administration, landscape planning, water conservancy, environment protection and so on departments work together, and strengthen the cooperation and communication among these departments, to manage the rainwater.

2) Site planning

When doing site planning, we should combine point, line, and plane as a network to manage the rainwater, and make full use of streets to control rainwater, which is the beginning of the rainwater management, to realize the goal of decelerate, filter, collection and reuse.

Another point during site planning is vertical design.

First of all, the designer should guide the rainwater flow in a reasonable direction based on the landform, to make the rainwater on the streets flow into the green naturally, make the extra water flow into the urban rainwater pipes, and finally the rainwater flow into the rivers. Then we can use different elevation to change the direction of flow, in order to prolong the time that the water flow into the pipes, so as to relieve urban waterlogging.

CONCLUSIONS

Only when we combine traditional roads and rainwater utilization together to make the original "gray infrastructure" into a "green infrastructure", the roads can truly become green street streets.

The features of green streets are: at ordinary times they just play a role of the landscape viewing, but when rainfall comes, they can play their treatment ability of water to collect and manage rainwater of the streets for the first time. The mode of green street is just like the picture in the below (Pic 13): it not only contains pavement, bike line and road way, but also includes some facilities like ecological ditches, greenbelts and rain garden. They all work together to make the green street function.

During this process, some rain facilities like rainwater cultivation pools become landscape pools. The excess rain further flow to the riverside areas or wetland parks in the city through the concave greenbelts or permeable pavements, when more rain comes, the urban drainage system will work to collect rainwater. However, greens streets cannot take the place of the system of city water managements, it just make the system more perfect and work effectively. The most important value of green streets is to reduce the instantaneous peak value of the rainwater when storm comes, in order to avoid the rain floods or urban waterlogging. Redundant rainwater still need to be managed through traditional urban drainage system.

Nowadays, China is developing rapidly, more and more cities are urbanizing. At the same time, the land used for roads has increased by a growth rate of 5% a year [14]. If all these lands are designed and managed in the way of green streets, it will bring immeasurable ecological benefits for the city. But this kind of sustainable mode of streets is just a link in urban storm water management, we cannot expect it to solve all the problems of rainwater. Only according to the government's macroeconomic regulation and control to form a whole network of urban rainwater managements, it is possible to realize the sustainable utilization of urban rainwater resources ecologically.

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