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# Practice of Sponge City Construction in a residential area of Tianjin

**Li Zhou*, Lu Tian and Xiaoping Li**

China Architectural Science Research Institute Co., Ltd., Beijing, China

*Corresponding author e-mail:pierozhou@163.com

**Abstract**. Taking a residential area as example, this paper introduced the designing strategies for the Sponge City Design Project in Tianjin. The geographical conditions, rainfall characteristics, the underlying surface conditions, vertical conditions, and drainage systems were analyzed to select the suitable low-impact development measures. It was found that the green lands, permeable pavements, and rainwater buckets had met the requirements for the control of total annual runoff, surface-source pollution control, and rainwater reuse required by the eco-city. The construction of the Sponge City Rainwater System will not only allow the building community to meet the evaluation criteria for green buildings and green communities, but also gain government support, increase the social awareness of construction developers, and increase social benefits. In addition, the Sponge City Rainwater System also brings good ecological benefits to real estate projects.

## 1. Project Background and Overview

Sino-Singapore Tianjin Eco-City, with a pilot area of approximately 2 square kilometers, is a demonstration project jointly approved by the Ministry of Housing and Urban-Rural Development and the Department of Natural Resources of Canada in June 2014.

The total land area of the project is 4,7179.4 $m^2$. The main functions are residential buildings, supporting public buildings and underground garages. The total construction area is 85,597.19$m^2$.

## 2. Geographical Conditions Analysis and Rainfall Characteristics

The eco-city is located in the northeast of Tianjin Binhai New Area. The average annual rainfall is 528.6mm, and the average annual rainfall days are 64 to 73 days. The average number of rainy days in the flood season is 42 days, and the summer rainfall accounts for 80%~84% of the whole year. The total amount of rainfall is small and varies significantly with the season. In order to reflect the demonstration effects, the eco-city is located in areas with poor natural conditions, land salinity, sparse vegetation, environmental degradation, fragile ecology and water shortages.

## 3. Design ideas

### *3.1. Analysis and Determination of Construction Objectives*

An eco-city in Tianjin is constructed with the concept of sponge city, which includes the construction of low-impact development rainwater system, drainage flood control system, water resources utilization system, and a water ecological environment security system, to build a demonstration area of a sponge city in the northern coastal area.

According to the conditions and construction conditions of each drainage sub-surface, author determines the annual total runoff control rate indicators.

The relationship between the design rainfall in the ecological urban area and the annual total runoff control rate is shown in the following Table 1.

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**Table 1.** relationship between the design rainfall and the annual total runoff control rate.

| Design rainfall | 12.2 | 14.4 | 17 | 20.3 | 24.4 | 29.5 | 36.3 | 45.6 |
|---|---|---|---|---|---|---|---|---|
| Annual runoff total control rate % | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 |

According to the requirements of the Sponge City Planning, the total annual runoff control rate is 75%, and the corresponding design rainfall is 24.4 mm. The runoff pollution control rate is 60%. Rainwater buckets are installed in the villa area, and rainwater reuse accounts for 1.0% of the average annual water consumption.

### *3.2. Status Analysis*

*3.2.1. analysis of the underlying surface.* According to the analysis of the overall situation, the greening rate of this project is relatively high and there is no need for roof greening. The roads in the community are impervious paving, and the kerbs and green land on both sides of the road are higher than the road, which is not conducive to rainwater infiltration.

The specific design ideas are as follows:

1) According to the analysis of the overall situation of the project, the greening degree of this project is relatively high. There is a large area of green land and landscape planting plants in the red line, and there is no need to increase the necessity of roof greening.

2) The residential roads are impervious paving the ground. The kerbs on both sides of the road are higher than the road surface, and the green land on both sides is higher than the road, which is not conducive to rainwater infiltration. Most of the local block roads are used by small-sized motor vehicles and have low load requirements. Therefore, the design of pervious paving is not carried out, and the design of the roads, walkways, etc. in the site is permeable.

3) The landscape plants are well-designed, and some of the green areas within the site are designed as recessed green spaces. The area of green spaces around some roads is small, so it is not easy to be recessed and therefore has not been designed. The area of green spaces surrounding some roads is relatively large and the ground covers are planted. Many, concave design.

4) Rainwater gardens are set up on the site to purify the water quality.

5) Adjust some of the road teeth and design the gaps of the road teeth to facilitate the flow of runoff from the pavement into the cleansing infiltration.

*3.2.2. Current drainage system.* 1) Rainwater from the roofs is adopts outer row rainwater system.2) Rainwater from the site is discharged into the municipal storm water pipe network.

*3.2.3. Vertical drainage conditions.* In the red line of this project, the terrain is generally flat, and the entrances and exits are respectively on the north of Xinping Road and on the south of Chuanbo Road. The designing elevation of the entrance and exit of the land and Xinping Road is 4.840m, which is higher than that of the municipal road. There is no danger of municipal rainwater pouring. The design elevation of the entrance and exit of the land and Chuanbo Road is 4.55m, which is higher than the elevation of the municipal road. The rainwater inside the block can be discharged to the municipal road.

*3.2.4. analysis of site soil conditions*. The eco-city is located in the north of Binhai New Area. Binhai New, covered by modern thick-bedded sediments with a sedimentary thickness of more than 1000m. The formation is dominated by the soft soil foundation of the Quaternary marine layer. The geological structure belongs to the Huanghua Depression Belt of the Xinhuaxia Structural System and is gestating with structural belts represented by the Haihe fault zone. The deep soil is formed by the interaction between river alluvium and marine sediments in modern times, with uniform texture, simple structure, the level is unknown, the soil viscous weight is brownish yellow, and the salt content is high. The fluvo-aquic soils are mainly distributed on the bank of the Minhang Canal. The saline soils are mainly

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distributed in the coastal areas and the towns and cities. The swamp soils are mainly distributed around the Yingcheng Reservoir. The content of physical clay less than 0.01 mm in soil is mostly above 45%, which is heavy loamy soil and light clay soil. At the same time, the soil structure is bad, the bulk density is high, the non-capillary gap is small, and the permeability is poor. According to soil soluble salt analysis results, the starting area is heavy saline soil area, soil salt content is generally 600 ~ 2000mg/100g soil samples, the main soil types are salinized wetlands, marsh coastal saline soil, coastal saline soil. Soil salinization in this region is strong and has a great influence on plant growth.

Therefore, the site must drain the salt before planting.

The drainage system of the greenland salt drainage system is connected to the municipal stormwater pipe network through the soft water pipe of De63 and the drain pipe passed through the salt drainage inspection well before passing through. The area where the row of salt-water aquifers is connected with the surrounding paving and roads is covered with geotextiles, and the non-woven fabric is used to isolate the showering layer from the planting soil. The depth of planting soil is determined according to the depth of planting soil the plants need. The drain trunk pipe is HDPE pipe, and the De63 drain pipe has a drain slope of 1%.

*3.2.5. Analysis of groundwater conditions.* The engineering groundwater is a quaternary surface void and is mainly found in the Quaternary Holocene clay. Groundwater mainly receives vertical infiltration of atmospheric precipitation, and lateral recharge of regional groundwater, and river water seepage. groundwater is discharged mainly by downstream runoff, ground evaporation and a small amount of agricultural water. The river water is salty-salt water, the total hardness is extremely hard, neutral-weakly alkaline, the chemical types of water are chlorine-sodium-potassium and bicarbonate-type. the groundwater is brackish-saline, and the total hardness is generally extremely hard Neutral-weakly alkaline: Most types of groundwater chemistry are chlorine-sodium-potassium type, partial water samples are chlorine-sodium-potassium-magnesium, chlorine-sodium-potassium-calcium, and bicarbonate sodium chloride.

According to the geotechnical survey report, the underground water level of the ground is as follows:

The initial water depth is 1.20~2.50m, which is equivalent to an elevation of 2.00~1.65m.

The static water depth is 0.70~1.70m, which is equivalent to the elevation of 2.53~2.45m.

Surface water is a type of submergence, which is mainly supplied by atmospheric precipitation and excreted in the form of evaporation. The water level changes with the season With an annual variation of about 0.50~1.00m.

## 4. Project Design

### *4.1. Brief introduction to the designing plan*

The focus of this design is mainly on water control and water storage to control rainwater displacement. According to the drainage zoning, combined with the surrounding land properties, green land rates, and water area ratios, et al, we comprehensively determine the type and layout of low-impact development facilities. Pay attention to the multifunctional use of public open space, make efficient use of existing facilities and venues, and combine rain control with landscape.

The green rate is high, while large green area is covered with planting in varied forms. Therefore, the main idea of sponge designing is to make full use of existing green space and avoid unnecessary facilities. The hard floor design is mainly designed to ensure functionality, retaining the design of the roadway, and setting the roads and pedestrian walkways into pervious concrete to increase the permeability. In the area where the road and the green land are adjacent to each other, the planting grass ditch and the recessed green area will be provided, and the rainwater outlet will be moved accordingly, and the hard surface runoff will be introduced into the green land to further promote the purification of the green space. Greenland rainwater outlet adopts osmotic rainwater outlet with interception function to control the initial runoff pollution.

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The sponge design is calculated by the volume method and the volume calculation formula is

$$V=10H\varphi F$$

Where, $V$ is design storage volume, $m^3$. H is design precipitation, mm. φ is comprehensive rainfall runoff coefficient. F is catchment area, $hm^2$.

### 4.2. Sponge Facilities and Storage Capacity Calculation

According to the calculation result, the storage volume is

$$47179.4\times0.578\times24.4/1000=665.38m^3$$

The calculation results for each partition are as follows:

The plot runoff is $664.88m^3$, and the actual storage capacity is $776.2m^3$, which meets the requirement of 75% of total runoff control rate.

### 4.3. Contaminant Removal Calculation

The low-impact development facilities in this project include rainwater gardens, sunken green areas, permeable bricks, and contaminated rainwater outlets.

Contaminated storm water outlets allow surface runoff rainwater to be collected by storm water outlets into the rainwater pipe network. Permeable submerged pavements can provide certain pollution interception to rainwater runoff. Rainwater gardens can be used to collect nearby rainwater for purification. Rainwater buckets can be used to collect and purify roof rainwater.

The SS concentration for the roof, roadway, pedestrian and green land is about 200mg/L, 270mg/L, 180mg/L, and 140mg/L respectively.

By weighted average calculation, the total SS removal rate is 50.73%, that is, the pollutant removal rate is 50.73%(in terms of SS).

### 4.4. Rainwater Utilization

Sunken green areas and permeable pavements receive rainwater to infiltrate in place. Considering that the underlying original soil has poor permeability, the design of permeable pavement design infiltration and drainage facilities.

Rainwater buckets are installed in every villa to collect water from the roof. The collected rainwater is used for greening irrigation, ground flushing of garages and roads, etc., in each courtyard. The rainwater is filtered through the rainwater bucket and the effluent quality must meet the requirements of Urban Wastewater Reuse City Miscellaneous Water Quality (GB/T 18920—2002).

The household water consumption per household is 120L/(per·d). the greening irrigation is 0.28m3/(m2·a), the road watering volume is 0.35L/(m2·times), and the annual tap water consumption is about 57330m3/a. According to the daily rainfall in a typical year, the rainwater bucket can be filled 13 times a year, and the annual amount of rainwater is $42\times13=546m^3$.

The rainwater utilization rate is 546/57330×100%=1%.

### *4.5. Sponge Facility Investment Calculation*

In this project, the sponge facilities are designed for the total annual runoff control targets. The sponge design used includes recessed green space, permeable paving, and rainwater buckets. The estimated investment in the sponge measures used in the project is shown in the table below.

**Table 2.** incremental cost.

| No. | Technology | Unit increment | Usage amount | Cost increment (yuan) |
|---|---|---|---|---|
| 1 | Recessed green space | 30 yuan/m$^2$ | 1702.35 m$^2$ | 187476 |
| 2 | Permeable pavement | 120 yuan/m$^2$ | 2875.9 m$^2$ | 345108 |
| 3 | Rainwater buckets | 3000 yuan | 42 | 126000 |
| 4 | Rain Garden | 150 yuan/m$^2$ | 1879.92 m$^2$ | 187476 |
| Total | | | | 804167 |
| Total construction area(m$^2$) | | | | 47179.4 |
| Unit area increment(yuan/m$^2$) | | | | 17.04 |

Note: 1. Partial incremental cost refer to Table F3-1 which in the standard of Sponge City Construction Technical Guide - Construction of Low Impact Rainwater Development System.

2. Rain bucket increments refer to the manufacturers quote.

## 5. Conclusion and Suggestions

Sponge City is a new model advocated by our country in urban development and construction.

The government actively encourages real estate projects to implement green building standards and build green ecological residential communities. The construction of the Sponge City Rainwater System not only allows real estate projects to meet the evaluation criteria of green buildings and green communities, but also gains government support. At the same time, it can increase the reputation for the real estate companies and bring great social benefits.

In addition, the Sponge City Rainwater System also brings good ecological benefits to real estate projects. Based on the design of low-impact development, using natural methods of drainage, through collection and purification, rainwater can be recycled for garden irrigation, flushing and cleaning to reduce natural water consumption and cost. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper.

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