Applicability Comparison of the Sponge Facilities in the Process of Sponge City Construction

Guo Chao[1,2,3,4]

[1]Shaanxi Provincial Land Engineering Construction Group Co., Ltd, Xi'an 710075, China;

[2]Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd, Xi'an 710075, China;

[3]Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of Natural Resources, Xi'an 710075, China;

[4]Shaanxi Provincial Land Consolidation Engineering Technology Research Center, Xi'an 710075, China.

Abstract

During the construction of sponge cities, commonly used sponge facilities are mainly used to reduce the amount of runoff water and purify runoff pollutants, so that the city has good "flexibility" in adapting to environmental changes and responding to natural disasters. This article mainly organizes the sponge facilities commonly used in the construction of sponge cities, compares the applicability of different facilities, analyzes their economics and landscape effects, and provides references for the further application of sponge facilities.

Keywords

Sponge facilities, Applicability, Sponge city construction.

1. Introduction

Urban roads carry a lot of pollutants due to tire wear, pedestrian shoe sole friction, dust in the air, industrial and construction waste. Under the effect of rainfall erosion, runoff rainwater will carry a higher concentration of pollutants, which is the main source of urban non-point source pollution, especially in the early stage of rainfall, where the pollution concentration is higher. The pollutants carried by rainfall runoff will be discharged into rivers or directly infiltrate along with rainfall runoff, which is the main source of groundwater replenishment, which not only pollutes rivers and lakes, but also affects the quality of groundwater [1]. Therefore, the reduction of urban rainwater runoff and the purification of pollutants are one of the urgent problems to be solved in municipal and environmental science [2].

Facing the serious problems of waterlogging, water pollution and lack of groundwater replenishment caused by traditional urbanization, people have put forward many countermeasures through reflection and research, such as the Sustainable Urban Drainage System (SUDS) in the United Kingdom and the low impact in the United States. Development (LID), Water Sensitive Urban Design (WSUD) in Australia, etc.[3], have achieved good results. Based on its own hydrological and geographical conditions, my country proposes to build a sponge city that is "naturally accumulated, naturally infiltrated, and naturally purified". During the construction of sponge cities, rain gardens and biological retention facilities are commonly used facilities for controlling rainwater volume and pollutants. These facilities can be collectively referred to as rainwater infiltration facilities (low-impact development stormwater management strategy—LID technology), which are not only efficient It is energy-saving, environmentally friendly and beautiful, and can improve the comprehensive drainage capacity of the catchment area. The most important thing is to reduce rainwater and purify the rainwater quality [4-5].

2. Comparison of the applicability of sponge facilities

In the process of sponge city construction, water volume control and water quality purification need to be considered comprehensively. Common sponge facilities are shown in Table 1.

Table 1 Common sponge facilities

Treatment facilities	Collecting and storing rainwater	supplementing groundwater	reducing peak flow	purifying rainwater	economics	landscape effects
Permeable brick paving	○	●	◎	◎	Lower	—
Permeable concrete	○	○	◎	◎	High	—
Green roof	○	○	◎	◎	High	Good
Biological retention facility	○	●	◎	◎	Lower	Good
Sunken green space	○	○	◎	◎	Lower	common
Vegetation buffer zone	○	○	○	●	Lower	common
Infiltration pond	●	●	◎	◎	medium	common
Rain wetland	●	○	●	●	High	Good
Artificial soil infiltration	●	○	○	●	High	Good
Reservoir	●	○	◎	◎	High	—
Seepage pipe/drain	○	◎	○	○	medium	—
Initial rainwater abandonment facility	○	○	○	●	medium	—

Note: ●—Best ◎—Good ○—Poor

Permeable brick paving and permeable concrete paving are mainly applicable to squares, parking lots, sidewalks, and roads with small traffic and load, such as building and residential roads, and non-motorized lanes of municipal roads. When permeable paving is applied to the following areas, necessary measures should be taken to prevent secondary disasters or groundwater pollution: (1) Areas that may cause steep slope collapse and landslide disasters, collapsible loess, expansive soil, and highly saline soil, etc. Special soil geology area. (2) Commercial parking lots, car recycling and maintenance points, gas stations and wharves that are frequently used in areas with serious runoff pollution. Permeable pavement has a wide application area and is convenient for construction. It can supplement groundwater and has a certain peak flow reduction and rainwater purification effect, but it is easy to block, and there is a risk of freezing and thawing damage in cold areas. In addition, the cost of permeable concrete paving is high and the economy is poor.

The green roof is suitable for flat roof buildings and sloped roof buildings with a slope of ≤15° that meet the conditions of roof load and waterproofing. Green roofs can effectively reduce the total amount of roof runoff and runoff pollution load, and have the effect of energy saving and emission reduction. However, there are strict requirements on roof load, waterproof, slope, and space conditions.

Biological retention facilities refer to facilities that store and purify runoff rainwater through plants, soil and microbial systems in low-lying areas. Biological retention facilities are divided into simple biological retention facilities and complex biological retention facilities, which are also called rain gardens, biological retention zones, elevated flower beds, ecological tree ponds, etc. according to different applications. Biological retention facilities are mainly applicable to the surrounding green areas of buildings, roads and parking lots in buildings and communities, as well as urban green areas such as urban road green belts. For areas where runoff pollution is serious, the bottom seepage surface of the facility is less than 1 m from the seasonal highest groundwater level or rock layer and the distance from the building foundation is less than 3 m (horizontal distance), complex biological retention facilities with bottom anti-seepage can be used.

Sunken green space is divided into a narrow sense and a broad sense. The narrow sunken green space refers to the green space that is lower than the surrounding paved ground or the road within 200 mm;

the general sunken green space refers to a certain storage volume (in the runoff When total amount control is the target for target decomposition or design calculations, adjustment volume is not included), and green spaces that can be used to regulate and store runoff rainwater, including biological retention facilities, infiltration ponds, wet ponds, rainwater wetlands, adjustment ponds, etc. Sunken green spaces can be widely used in urban buildings and communities, roads, green spaces and squares. For areas where runoff pollution is serious, the penetration surface at the bottom of the facility is less than 1 m from the seasonal highest groundwater level or rock layer, and the distance from the building foundation is less than 3 m (horizontal distance), necessary measures should be taken to prevent secondary disasters.

Vegetation buffer zone Vegetation buffer zone is a vegetation area with a slow slope. Through vegetation interception and soil infiltration, the surface runoff velocity is slowed down and some pollutants in the runoff are removed. The vegetation buffer zone generally has a slope of 2%-6%, and the width is not suitable Less than 2 m. The vegetation buffer zone is suitable for roads and other impervious surfaces. It can be used as a pretreatment facility for low-impact development facilities such as biological retention facilities, and can also be used as a waterfront green belt for urban water systems. However, when the slope is large (greater than 6%), its rainwater The purification effect is poor.

The infiltration pond is a depression used for the infiltration of rainwater to supplement groundwater. It has the function of purifying rainwater and reducing peak flow. Infiltration ponds are suitable for areas with large catchment areas (greater than 1 hm2) and certain spatial conditions, but they are used for serious runoff pollution, the bottom of the facility's seepage surface is away from the seasonal highest groundwater level or the rock layer is less than 1 m away from the building foundation In areas less than 3 m (horizontal distance), necessary measures should be taken to prevent secondary disasters.

Infiltration wells refer to facilities for infiltration of rainwater through the well wall and bottom of the well. In order to increase the infiltration effect, a horizontal seepage drainage pipe can be set around the seepage well, and gravel (gravel) can be laid around the drainage pipe. Infiltration wells are mainly used in the surrounding green areas of buildings and buildings in communities, roads and parking lots. When infiltrating wells are used in areas where runoff pollution is serious, the bottom of the facility is less than 1 m from the seasonal highest groundwater level or the rock layer and the distance from the building foundation is less than 3 m (horizontal distance), necessary measures should be taken to prevent secondary disasters.

Wet pond refers to a landscape water body with rainwater storage and purification functions, and rainwater is also used as its main water source. Wet ponds can sometimes be designed as a multi-functional water storage body in combination with site conditions such as green space and open space, that is, they can play normal landscape, leisure and entertainment functions at ordinary times, and they can play a regulating and storage function when heavy rains occur, realizing multi-functional utilization of land resources. Wet ponds are suitable for sites with spatial conditions such as buildings and communities, urban green spaces, and squares.

Rainwater wetlands use physical, aquatic plants, and microorganisms to purify rainwater. It is an efficient runoff pollution control facility. Rainwater wetlands are divided into rainwater surface wetlands and rainwater underflow wetlands. They are generally designed as an impermeable type to maintain the needs of rainwater wetland plants Rainwater wetlands are often built together with wet ponds and designed with a certain storage volume. Rainwater wetlands are suitable for areas such as buildings and communities, urban roads, urban green spaces, and waterfronts with certain spatial conditions. Rainwater wetland has high cost and poor economy.

Artificial soil infiltration is mainly used as a supporting rainwater facility for rainwater storage facilities such as reservoirs to achieve the quality of recycled water. The typical structure of artificial soil infiltration facilities can refer to complex biological retention facilities. Artificial soil infiltration is suitable for buildings and communities with certain site space and urban green spaces.

Reservoir refers to storage and utilization facilities with rainwater storage function, and also has the function of reducing peak flow. It mainly includes reinforced concrete reservoirs, brick and stone masonry reservoirs and plastic water storage modules assembled reservoirs. Most cities with tight land use underground closed reservoirs. The reservoir is suitable for buildings, communities, urban green spaces, etc. that require rainwater reuse. Corresponding rainwater purification facilities need to be built according to the use of rainwater reuse (greening, road spraying, toilet flushing, etc.); not suitable for no rainwater reuse. Areas that are heavily polluted by demand and runoff.

Seepage pipes/canals refer to rainwater pipes/canals with infiltration function, which can be made of perforated plastic pipes, sand-free concrete pipes/canals and gravel (crushed) stones. Seepage pipes/drains are suitable for areas with small transfer flow in buildings, communities and public green spaces, and are not suitable for areas with high groundwater levels, serious runoff pollution, and structural collapse that are not suitable for rainwater infiltration.

Initial rainwater abandonment refers to the abandonment of initial rainfall runoff that has an initial erosion effect and high pollutant concentration through a certain method or device to reduce the difficulty of subsequent treatment of rainwater. The initial rainwater abandonment facility is an important pretreatment facility for other low-impact development facilities. It is mainly suitable for the front end of low-impact development facilities such as rainwater pipes for roof rainwater and concentrated inlets for runoff rainwater.

3. Discussion

Urban rainwater runoff contains a lot of pollutants and is the main source of urban non-point source pollutants. The concentration of pollutants in rainwater runoff is mainly affected by meteorological factors such as rainfall intensity, rainfall, and dry period before rain[6], as well as other factors such as the type of underlying surface, the flow of people, the flow of vehicles, and the pollution status [7]. The collection and analysis of on-site runoff rainwater is an effective measure to obtain the concentration of rainwater runoff pollution in a region. Knowing the concentration of rainwater runoff pollutants in different regions can implement targeted treatment technical measures and make use of rainwater. For the loess areas with resource-based and water-quality water shortages and lack of groundwater replenishment, biological retention facilities are an important measure for rainwater treatment, which can achieve rainwater treatment effects, save costs, and improve landscape effects. It is the development direction of rainwater treatment technology in the later period.

4. Conclusions

In the process of sponge city construction, permeable brick paving and permeable concrete paving are mainly suitable for squares, parking lots, sidewalks, and roads with small traffic and load, such as building and residential roads, and non-motorized lanes of municipal roads. The green roof is suitable for flat roof buildings and sloped roof buildings with a slope of ≤15° that meet the conditions of roof load and waterproofing. The three have good adjustment effects on flood peak flow and rainwater quality, but the cost of permeable concrete paving is high and the economy is poor. For biological retention facilities, sunken green spaces, vegetation buffer zones, infiltration ponds, rainwater wetlands, artificial soil infiltration, etc., fillers or artificial soils with good permeability and pollutant adsorption performance are mainly used as backfills to carry rainfall runoff. The pollutants are naturally purified by physical, chemical, and biological effects such as filler adsorption, filtration, ion exchange, and microbial degradation, and then infiltrated to replenish groundwater or collected and reused. However, rainwater wetlands and artificial soils have high infiltration rates and poor economy. Reservoirs, seepage pipes/canals, and initial rainwater abandonment facilities mainly collect rainwater for centralized treatment. Its rainwater collection and utilization, water purification and other effects are better, but the cost is high and the economy is poor.

Acknowledgments

This research was financially supported by the project of Shaanxi Provence Land Engineering Construction Group (DJNY2020-27) and the project of Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group (2019-NBYY-29).

References

[1] Winslow D. H, William H. R, Aisha B, et al. Shifting ecological filters mediate postfire expansion of seedling aspen (Populus tremuloides) in Yellowstone[J]. Forest Ecology and Management, 2016, 362:218-230.

[2] Chen X L, Edward P, Belinda S M, et al. Nitrogen removal and nitrifying and denitrifying bacteria quantification in a storm-water bioretention system[J].Water research, 2013, 47:1961-1700.

[3] Fletcher T D, Shuster W, Hunt W F, et al. SUDS, LID, BMPs, WSUD and more-The evolution and application of terminology surrounding urban drainage[J].Urban Water Journal, 2015, 12(7): 525-542.

[4] Deitz M E. Low impact development practices: a review of current research and recommendations for future directions[J].Water Air Soil Pollution, 2007, 186:351-363.

[5] Roon V M. Emerging approaches to urban ecosystem management: The potential of low impact urban design and development principles[J].Journal of Environment al Assessment Policy and Management, 2005, 7(1):125-148.

[6] Tang S C, Luo W, Jia Z H, et al. Effect of rain gardens on storm runoff reduction[J]. Advances in Water Science, 2015, 26(6):787-794.

[7] Li J K, Jiang C B, Zhang S C, et al. pilot scale experiments and simulation of the purification effects of bioswale on urban road runoff[J]. Advances in Water Science, 2016, 27(6):898-908.