Application Analysis of Low Impact Development in Sponge City Construction

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Abstract. Low impact development is an important means of Sponge City Construction, an effective measure to reduce a series of severe ecological problems such as frequent water logging, loss of water, serious runoff pollution, urban ecological environment damage and so on in the process of decreasing urbanization development, and an ecological technical system for the safety and security of water. By discussing the practical significance of low impact development, this paper reviews the practical cases of typical low impact development—GuiYang. Finally, puts forward the path of making full use of low impact development in urban planning.

1. Introduction
At the end of the 1920s, LID was gradually developed, which is a kind of technology for rainstorm management and non-point source pollution treatment whose purpose lies to effectively control the runoff and pollution caused by rainstorm by the use of decentralized and small-scale source treatment means when developing the site so as to maximize the maintenance of the developed original and natural-state hydrologic cycle.

LID can be divided into broad sense and narrow sense. In the broad sense, LID aims at reducing or eliminating the damage and impact of urban construction on the original eco-hydrological cycle in the process of urban development, so as to protect and restore the ecological environment. LID, in a narrow sense, refers to a series of ecological technology systems that can make urban rainwater collection, recycling and reuse come true. The key lies in natural purification, in-situ collection, recharge of groundwater and nearby utilization and the main measures include: rainwater park, ecological grass planting ditch, green roof, permeable pavement, concave-type green space, underground infiltration and so on.

2. Analysis of practical application of LID
Input construction of LID facilities should be coupled with specific hydrogeology, land use, density of surrounding buildings and other actual situations, in accordance with the overall development plan of the city and the targets formulated by special construction planning, it is necessary to consider and evaluate the function, value, applicability and landscape effect of facility construction comprehensively and make the best choice. The applicability of the specific facilities planning should be in line with the actual conditions of urban soil permeability, landform, topography, landform, groundwater level and spatial density, etc.[1] The infiltration of precipitation should avoid pollution to
underground water sources, not bring bad influence to the residents' life in the area. It shall not adversely have an effect on the life of the residents in the area, destroy the original ecological environment, or endanger the safety of the buildings in the area.

2.1. Application of LID in public green space
Public green space includes park green space, roadside green space and so on, which is a relatively closed green space system. The system includes green space, roads, buildings, etc. The investment of low impact development in public green space should take infiltration, purification, storage and recycling of rainfall as the purpose. The input of these facilities is jointly complementary to the conduit system in this area. By reducing surface runoff and increasing rainfall infiltration rate, the maximum utilization of rainfall resources can be achieved, and the sustainable utilization of rainfall in public green space can be achieved eventually.

Public green space is based on the premise of satisfying its own landscape functions, adopting matching low impact development, such as rainwater gardens, grass planting ditches, permeable pavements, vegetation buffer zones, and artificial wetlands to carry out the planning of special projects. These adapted facilities are necessary to meet the low-impact development targets such as greening rate, runoff control rate and permeability rate proposed by the special planning. The rainfall utilization mainly focuses on soil infiltration, natural water supply and ecological purification cycle. In principle, high cost purification facilities should be avoided. The main form of public green space with low infiltration rate is water storage and circulation, and the landscape water body in public green space should be adapted to landscape design and used as rainfall storage equipment. Landscape water bodies should be with overflow. If there is superstandard phenomenon, it can be discharged through the municipal pipe network. In addition, the landscape water bodies can be combined with storage equipment, wetland facilities. After a series of treatment, such as filtration and rainfall, the rainfall is used for surface green planting irrigation to realize the recycling of water resources. According to the relevant requirements of the "Park Design Code" (CJJ48-92)[2], the vegetation selected for LID technology should be in line with local water conditions, rainfall quality, in addition, drought resistance, waterlogging resistance and pollution resistance should be the first choice.

2.2. Application of LID in square green space
Compared with the park green space, the square green space is relatively much open. The low-impact development that this type of green space should use is necessary to focus on rainfall infiltration, storing and purification, and "digesting" the runoff rainwater from itself and its surrounding sites. The overflow rainwater enters the municipal rainwater pipe network by means of the super-standard rainwater runoff drainage system and the rainwater conduit system.[3]

Square green space shall implement "digestive treatment" for the rainfall by the use of low-impact development facilities such as permeable pavement, grass planting ditch, artificial wetland, rainwater garden and green parking lot, etc. The square shall adopt permeable materials to infiltrate the rainfall so that the groundwater can be supplemented; while using the permeable materials, the reasonable setting of slope should be also carried out to ensure drainage (generally, it should be 3% tilted), and the inclined pavement shall enable the surrounding green space to absorb and utilize the rainfall promptly and reasonably; because the surface runoff of 10-15mm dissolves a lot of polluting gases in the initial stage of rainfall, in order to effectively avoid the initial rainwater pollution, the roads beside the factories and motor lanes should be equipped with initial rainwater extraction devices. After collecting the part of surface runoff, it should be centrally purified and treated and then discharged through the municipal rainwater pipe network. In addition, a series of LID technologies should be adopted by green parking lot to make up for the impermeable area of the parking lot pavement.

2.3. Application of LID in the road green land
Road green space belongs to open green space, which should take "infiltration, storage, purification and utilization" as the main function and "digest" the runoff rainwater of itself and its surrounding
environment when applied to LID. Permeable brick, rainwater garden, artificial wetland, grass planting ditch and other LID facilities should be used in the road green land to treat runoff and rainfall. The pavement should use permeable materials to infiltrate the rainfall into the underground in time, so as to effectively supplement the groundwater; while using permeable brick, the road should be inclined to the surrounding green land to a reasonable degree of slope, so that the green land can help to absorb rainfall; taking into account the problem of rainwater pollution at the initial stage of motor vehicle lane, the road rainwater should be set up purification device before recycling, after rainwater with high pollutant content is centralized and treated, then it should be discharged to the municipal rainwater pipe network.

In the construction planning of road green space, it needs to appropriately widen the space reserved for green infrastructure. In terms of the actual conditions of road longitudinal slope and municipal rainwater pipe network, etc, grass planting ditch drainage should be given priority. Bicycle paths, sidewalks and other roads with less bearing pressure can be preferentially permeable bricks and other materials. The trees next to sidewalk should first be planted with permeable tree pools to absorb trunk runoff and surface runoff. Green planting beside roads should ensure the soil conditions and growth conditions needed by vegetation, eliminate the soil stagnant-water layer, and ensure the growth of green planting. In order to adapt to LID, road green planting should be selected in accordance with the regional runoff, rainfall volume, water quality conditions. Generally, waterlogging resistance, drought resistance and plants with strong pollution resistance should be preferred.

Road green space integrates the permeable road surface, vegetation water absorption and green landscape and integrates urban roads into rain infiltration, filtration, storage and utilization devices by means of permeable brick and green infrastructure, etc. in order to achieve the reduction of rainfall runoff, the reduction of non-point source pollution and the purification of vehicle exhaust pollution. A series of the applications of LID make it possible to take the place of "fast drainage" with "slow permeation". (List of selection of low-impact development facilities is shown in table 1, List of selection of low-impact development facilities is shown in table 2).

**Table 1. List of selection of low-impact development facilities**

| Single facility                          | Function               |
|-----------------------------------------|------------------------|
|                                         | Collecting and utilizing rain water | Replenishing groundwater | Reducing peak flow | Purify rain water | Transmission |
| Permeable brick pavement                | ○                      | ●                      | ○                  | ○                  | ○           |
| Green roof                              | ○                      | ○                      | ○                  | ○                  | ○           |
| Sunken green space                      | ○                      | ○                      | ○                  | ○                  | ○           |
| Simple biological retention facility    | ○                      | ●                      | ○                  | ○                  | ○           |
| Rain-water wetland                      | ●                      | ○                      | ●                  | ●                  | ○           |
| Reservoir                               | ●                      | ○                      | ○                  | ○                  | ○           |
| Rainwater tank                          | ●                      | ○                      | ○                  | ○                  | ○           |
| Regulation pond                         | ○                      | ○                      | ●                  | ○                  | ○           |
| Regulation pool                         | ○                      | ○                      | ●                  | ○                  | ○           |
| Transposition type of grass planting ditch | ○                      | ○                      | ○                  | ○                  | ●           |
| Leaky pipe                              | ○                      | ○                      | ○                  | ○                  | ●           |
| Vegetation buffer zone                  | ○                      | ○                      | ○                  | ●                  | -           |
| Initial rainwater abandonment facility  | ○                      | ○                      | ○                  | ●                  | -           |
3. Key points of design for common facilities in low impact development

3.1. Permeable pavement
Permeable pavement can be divided into permeable brick pavement, permeable cement concrete pavement and permeable asphalt concrete pavement according to the surface material. The permeability coefficient of permeable layer should be greater than $1 \times 10^{-4} \text{ mm/s}$ and the permeable surface brick, permeable concrete, lawn brick and others can be used. When the surface layer can be planted, a certain proportion of nutrient soil should be mixed in the underlying layer. The effective porosity of permeable brick should not be less than 8%, and the effective porosity of permeable concrete should not be less than 10%. The permeable layer should adopt fine stone permeable concrete, dry sand, crushed stone or stone debris, etc and the permeability coefficient and effective porosity should be no less than the surface layer, and the thickness should be 20~50mm. The thickness of permeable cushion should be determined according to the requirement of water storage and the emptying time of stored rain water. The thickness of permeable cushion should not be less than 150mm and the porosity should not be less than 30%. The slope of permeable pavement should not be more than 2.0%. When the slope of permeable pavement is more than 2.0%, the spacer should be set up along the length direction, and the top of the partition should be set 2~3cm below the permeable layer and the HDPE or PVC impervious film or concrete that is larger than 16mm can be used as the barrier. In order to prevent rain water runoff from blocking the permeable pavement, small sedimentation tank and front pond should be used to pre-treat the runoff of rain water road before it enters the permeable pavement. The structure of permeable pavement should be convenient for construction, good for maintenance and reduce the influence on surrounding environment and ecology, which should satisfy the relevant provisions of "technical specification for permeable cement
concrete pavement"(CJJ/T135), "technical specification for permeable asphalt pavement"(CJJ/T190), "technical specification for permeable brick pavement"(CJJ/T188).[4]

3.2. Grass planting ditch
Grass planting ditch are generally divided into four categories, such as grass canals, dry grass grooves, wet grass grooves and permeable grass grooves. Grass planting ditch are not suitable for areas where the groundwater level is high and the slope is greater than 15%. Plant grass filter buffer zone should be set up at the entrance of grass planting ditch to remove the pollutants with larger particle size in rain water runoff. The upstream catchment area of grass-planting ditch should not be greater than 0.8ha, the width of vegetation ditch should be 0.6~2.4m, the depth should be 0.1×0.3m, and the length of ditch should not be less than 30m. Section form should be inverted parabola, triangular or trapezoidal. Slope (vertical: horizontal) of grass ditch should not be greater than 1:3. The longitudinal slope should not exceed 4.0%. If the slope is more than 4.0%, the grade control structure should be set up to control the slope within 4.0%. The grass-planting ditch medium layer usually consists of planting soil layer, filtration layer, infiltration/storage layer. The design depth of planting soil layer should not be less than 300 mm, the design depth of filter layer should be 100mm, and the design depth of infiltration/storage layer should not be less than 50mm. The permeability of soil medium in grass planting ditch should be no less than that of 1.3cm/h. For grass-planting ditch, the minimum thickness of soil layer should be 0.6m; for the grass-planting ditch where trees and shrubs are planted, the minimum thickness of the soil layer is 0.9m. The influent velocity of vegetation layer in grass-planting ditch should not be more than 0.3m/s, and that of vegetation layer should not be greater than 0.9m/s. The maximum flow velocity in the planting ditch should be less than 0.8m/s, and the Manning coefficient should be 0.2-0.3. Grass-planting ditch should be provided with diversion or internal overflow measures, which is used to exclude rain water beyond the design standards. The stored rain water should be infiltrated into the soil layer within 24hours in the grass planting ditch. In areas with higher environmental quality and safety requirements, 12hours of complete infiltration should be adopted. The stored rain water should be completely infiltrated below the soil layer within 48hours in the planting ditch at a depth of 0.6×0.9m. The furrow should be planted with dense turf, trees and shrubs should not be planted, and the height of vegetation should be controlled at 0.1×0.2m.[5]

3.3. Biological detention facility
Biological detention facility is usually located at the source of runoff, including green roads, parking lots, dense buildings, and so on, which is not appropriate to build areas where the slope of the ground is greater than 20% and where mature tree replacement sites need to be excavated. The slope requires that the biological detention facility should be designed as flat bottom while vertical slope should not be adopted. The designed slope should be less than 1:2 (vertical distance: horizontal distance), which should be 1/4; the designed slope of vegetation slope should be less than 1/3. The design surface area of the biological detention facility should be determined by the calculation of the upstream catchment area and the impermeable rate. The construction area should not be less than 2 square meters and the upstream catchment area of the biological detention facility should not be greater than 2ha. The biological detention facility usually include water storage layer, covering layer, planted soil layers, isolation layers, drainage / infiltration layer. The thickness of the water storage layer is typically 200 to 300mm and the superelevation of the 100mm is set; the thickness of the covering layer is usually 70~80mm; the thickness of the planted soil layer is generally 600~1200mm; the thickness of the isolation layer is generally geotextile or sand layer that is not less than 100mm (coarse sand and fine sand); the thickness of drainage / infiltration layer is generally 300m/1000mm. Rain water inflow velocity should not be greater than 0.3m/s in cover-type biological-detention facility, and the inflow velocity of rain water in vegetation and grass-planting biological detention facility should not be greater than 0.9m/s. In general, overflow ports should be set up at the top of the water storage layer in biological detention facilities, and the maximum height difference between the overflow port and the designed water surface of the water storage layer should not exceed 100mm. The accumulation of rain
water in the bio-detention facility should be infiltrated into the planted soil layer within 24 hours. In areas with high environmental quality and safety requirements, 12-hour complete infiltration should be adopted. The accumulation of rain water in the biological detention facility should completely penetrate to the depth of 0.6~0.9m below the planted soil layer within 48 hours.

3.4. Green roof
Green roof is suitable for slop roof building with structural safety, waterproof conditions of flat roof and with slope not greater than 15 degrees, and it's preferred layout in multi-storey buildings and larger building skirt building. Green roof planting soil should use improved soil or inorganic compound planting soil, which is prohibited to use triad soil, stone slag, expansive soil and other soil as planting soil. The thickness of planted soil should not be less than 150mm. The design of rain water drainage system for green roof should meet the requirements of "code for design of rain water drainage system of building roof" (CJJ142-2014). The drainage slope of green roof should be 1% ~ 2%, and the structural slope should be adjusted when the length of one-way slope is more than 9m. The materials in green roof should be selected in accordance with the current national standards, that is, "Roof Engineering Technical Specification" (GB50345-2012), "Planting Roof Engineering Technical Specification" (JGJ155-2013). Root-resistant puncture waterproof material should be in accordance with the relevant national standards, and qualified inspection reports should be issued by qualified inspection agencies. Drainage (storage) materials shall not be used as root-resistant puncture waterproof material. The plant selection of green roof should be in accordance with the principle of plant diversity and symbiosis, take the plants with relatively stable growth characteristics, ornamental values, and with strong dust retention and temperature control ability, which are commonly used locally and introduced successfully as the focus and then give priority selection of low shrubs, lawns, and ground cover plants, etc.

4. Conclusion
If a city wants to develop, it will inevitably undergo different changes, and there is also new problems happening during its development, which requires new measures to solve. LID is as an important approach to the construction of sponge cities whose purpose is to maintain the hydrological characteristics before and after development in the region, minimize the damage to the original ecological environment as far as possible, reduce the pressure of rainfall discharge on municipal pipe network, reduce the surface runoff to the pollution of water quality, forming an ecosystem with "rainwater is effectively controlled, and pollution is effectively prevented", which not only accords with the requirements of the ecological civilization construction of China, but also meets the objectives of urban rainwater treatment planning.

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