Research on the Design of Comprehensive Storm Flood Prevention and Treatment Project of Sponge Airport

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Abstract: In view of the current situation that the airport is often flooded in recent years, based on the analysis of comprehensive storm flood prevention and treatment measures in different regions, this paper puts forward the overall framework scheme for the spatial layout design of comprehensive storm flood prevention and treatment project of sponge airport, and focuses on the composition of purification function, workflow process and large-scale release function of new storage tank, so as to promote the new-type “assembled” and “modular” regulation innovative application of storage tank.

1. Introduction
The airport construction broke the original natural environment of the site, and added many hardened areas such as terminal buildings and runways, which brought about the increment of the total amount of rainwater runoff and the peak runoff. In addition, extreme rainstorm weather frequently occurred, and airport flooding events are common. Such as in August 2015, heavy rain caused serious water accumulation at Shanghai Hongqiao airport apron, leading serious impounded surface water. And the rainstorm in 2018 caused 187 flight delayed at Chengdu airport and 13000 passengers were stranded, resulting in heavy social and economic losses. In order to deal with the flood and improve the large drainage system of the airport, the design concept of balancing pool at Gatwick Airport in London is used as reference. This paper will study the technology of comprehensive storm flood prevention and treatment in sponge airport based on the design of the new type storage tank in sponge airport \cite{1-4}.

2. Trend of Comprehensive Storm Flood Prevention and Treatment Measures to Sponge Airport
2.1 Layout of Sponge Measures to Different Airports
When planning the prevention measures to rain and flood, the new/expanded airport should take its goal as the guide, deeply exploring its natural conditions such as the hydrogeological characteristics of water source. Combined with the construction requirements of sponge airport in water safety, water ecology, water environment and water resources, comprehensive measures are supposed to be set up in different areas, stages and levels to solve the obstacles in development, comprehensive management and control, to prevent the recurrence of problems.

The reconstruction airport encounters kinds of noticeable predicaments such as high development intensity, many limiting factors, and limited space for reconstruction and optimization. Therefore, the comprehensive storm flood prevention and treatment measures of such sponge airport should be problem-oriented. According to the current situation of water safety, water ecology, water environment and water resources of the reconstructed airport, the construction status of each
functional area should be sorted out, and the reasonable improvement should be determined based on the composition of comprehensive storm flood prevention and treatment system of “low impact development system + Airport small drainage system + Airport large drainage system”, building a model to solve the existing airport waterlogging and water quality deterioration problems.

2.2 Collaboration between the Airport Source Low Impact Development System and the Airport Small Drainage System

The low impact development facilities at the source of the airport can alleviate the pressure of the drainage network of the airport pipes and canals through infiltration and retention, reducing the airport flood, and improving the rainwater quality through the primary purification. At present, even though there are hydrological models such as SWMM can be used to study the improvement of drainage system of low impact measures and the pipeline drainage network has participated in the relevant research, it only serves as a fixed system boundary, without discussing its hydraulic and spatial distribution characteristics and the relationship with low impact development facilities. The low impact development facilities at the source of the airport belong to the micro scale measures. From the spatial layout, they are scattered and point-like, while the airport small drainage system (i.e. the traditional airport pipe drainage system) is linear and network-shaped. They are interrelated and cooperate with each other, jointly dealing with the rain water in the return period of low rainstorm.

2.3 Assembly and Modularization of Airport Drainage Measures

The setting environment should be fully considered when distributing storm flood prevention measures. Different from other areas, the airport has more hardening area which accounts for a large proportion, and the air side runoff may be polluted by deicing fluid, resulting that the runoff cannot be reduced by simply adding permeable pavement. What’s more, due to the particularity of airport, the strength of permeable pavement is required to be higher. Besides, the scheme of reducing runoff by planting native vegetation or green roofs in other areas is not necessarily suitable for airports. The original vegetation and green roof may increase the attraction to wildlife, which are the potential danger of flight safety.

To build the sponge airport industry chain, factors such as the design of permeable pavement (strength, smoothness, stability), green roof vegetation selection (easy maintenance, low drought tolerance) and reservoir design (decontamination, water storage capacity) can be the starting points, forming the sponge airport industry chain with each other in series, airport drainage system measures assembly, and joint prevention and treatment of airport flood(Fig 1).
3. Space Layout Design of Comprehensive Storm Flood Prevention and Treatment Project in Sponge Airport

3.1 Design Objectives and Principles

3.1.1 Natural storage. The construction of the airport destroys the ecological conditions and hydrological characteristics of the site background, and weakens the function of natural seepage storage and purification of the site. The construction of comprehensive storm flood prevention and treatment project of sponge airport needs to respect nature, learn nature and be close to nature under the premise of ensuring airport’s safety of production and life. In the development and construction of the airport site area, not only the protection of ecological sensitive areas such as lakes and streams should be taken into consideration, the rational use of the natural water system around the airport is also of vital importance. The comprehensive storm flood prevention and treatment project of sponge airport based on “natural regulation and storage” should start from two aspects: The first one is imitating the natural seepage process and making full use of the surrounding natural environment and natural lakes, comprehensively realizing the internal “airport low impact development measures + airport small drainage system + artificial large drainage system” to prevent waterlogging. Another is in the external that “jointing control of river and lake” to resist flood, so as to jointly guarantee the normal operation of airport in rainy and flood season.

3.1.2 Graded Management and Storage. Based on the concept of sponge airport, the prevention and treatment of storm and flood in airport is a long-term and complex municipal foundation project, which requires the cooperation of various disciplines and departments such as airport planning, garden, municipal and so on. Therefore, the spatial layout design of the sponge airport comprehensive storm flood treatment project should proceed from the top level design, planning the control system as a whole, formulating the integrated storm flood control target (including total runoff, runoff peak flow, runoff pollution control rate and rainwater reuse rate, etc.), comprehensively taking ways such as...
“seepage, stagnation, storage, net, use, discharge” and so on, and decompose the integrated treatment target to all levels accorded with the whole frame and system of “airport low impact development + airport small drainage system + airport large drainage system”, making all regulation and storage engineering facilities be set up based on various levels.

3.2 Design content

3.2.1 Development and improvement of the airport small drainage system in combination with the low impact of the airport source. The main paving surface of airport flight area is load-bearing pavement which can bear the load of aircraft. The impervious paving area is large, requiring high standard drainage and waterlogging prevention (Table 1).

| Regions          | Characteristics                          | Measures                      |
|------------------|------------------------------------------|-------------------------------|
| Area of flight   | Serious non-point source pollution, large area of impervious pavement, high standard of drainage and waterlogging | Rainwater ditch, grass ditch |
| Terminal area    | Initial stage rainfall runoff pollution  | Green roof, permeable gutter  |
| Work area        | Serious non-point source pollution and oil pollution in rainwater runoff | Non-power oil separation sand well, oil separator |
| Maintenance area | Presence of point source or non-point source pollution | Permeable pavement, permeable gutter |
| Oil depot area   |                                          |                               |
| Freight area     |                                          |                               |

3.2.2 Construction of a New Storage Pool to Improve the Large Drainage System at Airport. Airport Rain Water Storage Pool is an important control measure of airport rainwater runoff, which aims at regulating the peak flow of rainstorm. At present, China’s airports’ large-scale storage facilities are mainly rainwater storage tanks located at the end of runway or terminal area. However, according to the requirements of sponge airport construction concept, the utilization of artificial rainwater storage tanks in China is not that reasonable because of the lack of purification function, large occupation of area and high expenditure. Obviously, the Chinese airports’ rainwater storage pool can draw lessons from the design of the balance pool of London Gatwick airport, realizing the “balance of the storage pool”, building a new type of rainwater storage pool, and achieving the deep purification of the rainwater runoff while accommodating the rainstorm runoff.

4. Functional Composition of New Storage Tank
In response to the flood of the airport, the new storage tank of sponge airport has the dual goals of accommodating the excess rainstorm water and treating the runoff to remove the pollutants. The new storage pool of sponge airport can be further divided into primary rain storage pool (Fig 2) which collects relatively clean rain water from the land side and flood storage pool (Fig 3) that collects more polluted runoff from the air side runway. Therefore, the new storage tank of sponge airport, which can achieve the above goals, should have both purification function and large-in-release function.
4.1 Purification function

The empty side runoff may be contaminated by hydrocarbons in aircraft fuel, deicing fluid residues (the main component is ethylene glycol), etc. Ethylene glycol is soluble in water with sweet taste. The deicing fluid is discharged with rain to the downstream paddock river, which can facilitate the propagation of bacteria in the river channel. Bacteria cover the river bed, forcing aquatic insects and fish to leave the area and reducing dissolved oxygen levels. Therefore, a storage tank with purification function is needed, so that the empty side runoff can be transported from the airport to here for detention and treatment through the reinforced concrete pipes, and the clean rainwater is discharged from the new storage tank to the downstream paddock river. Besides, rainwater in the terminal area, working area and other areas is relatively clean, but the initial landing rain water dissolved a large amount of polluting gas in the atmosphere. Landing terminal, working areas and roads are scoured by these rains, resulting in a further increment of pollutants in the rain water. Therefore, the rain water in these areas should also be disposed and purified before discharge or use.

4.1.1 Rainwater filtration system

The rainwater flowing from the empty side into the new storage tank can be filtered through four steps to be purified: (1) Using filter screen to intercept solid waste; (2) Adding oxygen to treat ethylene glycol with natural fungi and bacteria; (3) Filter solid waste; (4) Treating residual ethylene glycol with natural fungi and bacteria. The rainwater in these areas should also be disposed and purified before discharge or use.
glycol; (3) Using natural bacteria and fungi to decompose other pollutants and residual ethylene glycol into carbon dioxide and water; (4) Further cleaning rainwater.

Water flows through the filter screen to intercept solid waste and go into the new storage tank. The new storage tank consists of three different chambers with a siphon of each one. When the rain reaches a predetermined height, the siphon activates the water and pulses into the next chamber (replacing the pump with a siphon). The whole stone bottom layer of the first chamber is placed with a pinhole tube and installed with a pump to pump oxygen, which is a more effective method of ethylene glycol treatment. Then, the rain water reaches the second chamber through the pipe distribution system. The treatment chamber consists of a layer of geotextile covered by multiple layers of different sizes of stone, which is still covered by a layer of covering and grass. Here, natural bacteria and fungi decompose residual ethylene glycol and other contaminants into carbon dioxide and water. As the water level in the second chamber rises, the siphon activates the siphon tank and releases the treated rain water to the third chamber. The bottom of the chamber has a stone covered with bacteria, which can further treat the rain water. The final treated clean water can be discharged to the downstream paddock river.

Setting up the initial rain water abandonment devices before the rain fall pipes of roofs of the terminal building, working area and other land side function partition rain water runoff centralized entrance is an effective way to deal with the rain water. The initial high-polluted rain water flows through the sewage pipe connected to the municipal sewage pipe system, and then goes into the sewage treatment plant centralized treatment. The whole procedure largely reduces the difficulty of land side rain water treatment. Therefore, the filtration system of the primary rain storage tank is simpler than that of the flood storage tank. The reasons are as follow: (1) The waste debris is removed by the powder grid, and the solid-liquid separation of the runoff pollution is realized by the primary settling tank; (2) The inorganic chemical components such as nitrogen and phosphorus in the runoff and other kinds of organic matter are easily dissolved in the rainwater by intelligent aeration, which uses microorganisms to remove and decompose the pollutants such as nitrogen and phosphorus in the runoff; (3) The ion deodorization technology is used to purify runoff in depth for the pollutants and toxic substances that may be produced in the second step purification.

4.1.2 A New Anti-Seepage System for Storage Tank. According to the concept of “green, low-carbon, ecological and sustainable” airport construction in China, in order to reduce the pollution of groundwater quality, the anti-seepage system should be set up in the new storage tank as the transfer station of rain flood regulation and storage from the point of view of airport water ecology and water environment.

In order to realize the anti-seepage function, the traditional airport storage tank mostly builds the storage tank into concrete and other impermeable water surface. Geomembrane is a kind of anti-seepage material which is made of plastic film as anti-seepage base material and non-woven fabric. As a new type of anti-seepage material, the composite geomembrane has the characteristics of high tear strength, good extension performance, large deformation modulus, aging resistance, good anti-seepage performance and long service life. It can be laid at the bottom of the new storage tank to prevent soil erosion caused by dirty rainwater. Laying the protective geotextile liners on its lower layers can also be helpful to prevent sharp stones that may damage the film.

4.2. Absorb Large Release Slow function
The construction of sponge airport aims to restore the natural hydrological behavior before the airport is developed. Before the development of the site, the rain water can be discharged into the downstream paddock river through natural vegetation, seepage, stagnation, storage, net, etc. However, after the construction of the site, the time spent from landing to discharge into the nearby canal and the downstream paddock river is much shorter than before, and the quantity of runoff is also larger. One of the functions of the new storage tank is that it can accommodate the excess rainstorm water and control its discharge speed and flow rate. Archimedes spiral pump is a kind of pump-like device
5. Summary
Sponge airport storm flood prevention and treatment project is still in its infancy in China. The application of the airport in water permeable pavement and green garden is still less, and the way that airport deals with extreme rainstorm weather is mainly through the construction of traditional storage tank. It is necessary to build comprehensive storm flood prevention and treatment measures of sponge airport with the goal of “natural regulation and storage” and “graded regulation and storage”, constructing the industry chain of sponge airport, realizing “assembly type” and “modularization” of storm flood prevention and treatment measures of real sponge airport, and actively promoting the construction of new storage pool.

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