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SPONGE CITY CONSTRUCTION IN XIAMEN, CHINA

BY JIAHONG LIU, CHENYAO XIANG, WEIWEI SHAO, YONG LUAN

Sponge city construction is a key mission of urban development plan in China's 13th Five Year Plan, and Xiamen is in the group of 16 pilot sponge cities in China. Xiamen is located in the southeastern coastal region in China, with a subtropical maritime monsoon climate and an urban population of over 4 million. The local water resources are very unevenly distributed during the year, resulting in double threats of urban flooding and water shortage.

On September 19th, 2016, with the landing of Typhoon Meranti, Xiamen suffered winds of up to force 17 in the Beaufort scale, a short-time rainstorm, and severe waterlogging. Meanwhile, Xiamen's aquatic environment is facing great challenges. In recent years, water quality in over 80% of local streams is below Class V, the worst category in the national surface water quality standards.

In 2014, Xiamen initiated the sponge city construction project which contains 4 major parts: (1) controlling surface runoff through Low Impact Development (LID) implementation; (2) extending the storage capacity of the local river-lake system to contain stormwater through water body renovation and ecological restoration; (3) controlling pollution sources by rebuilding combined sewer systems, raising interception ratio and wastewater treatment capacity, so as to improve the local aquatic environment; and (4) building basic stormwater draining infrastructure to prevent urban flooding and waterlogging.

Sponge city implementation in Xiamen

According to the design of the Xiamen sponge city construction project, the built-up area of the city is divided into 16 drainage districts. Sponge community, sponge roads, eco-river systems, pollution management infrastructure and drainage installations are constructed according to each district's feature. The overall objective is to accommodate 70% of the annual rainfall in the built-up region.

Low Impact Development (LID) of communities and roads

LID for residential communities and roads are also called "sponge community construction" and "sponge road construction". Currently

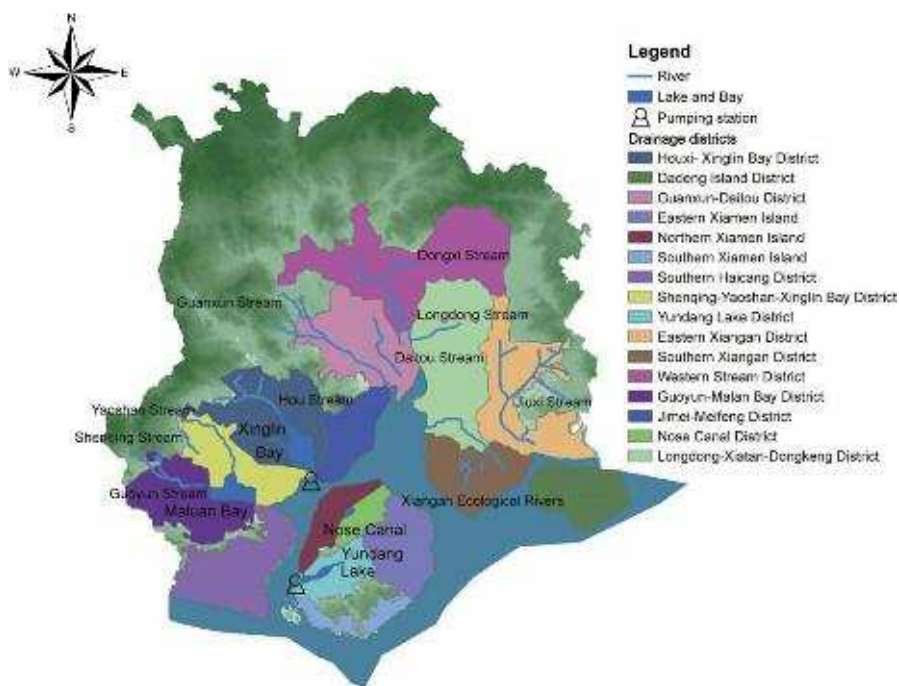


Figure 1. The drainage districts of Xiamen sponge city

Xiamen has launched sponge community projects in Guoyun-Malan Bay and Southern Xiangan districts. These 2 projects cover an area of 41.76 km², 12.9% of the city's total built-up area. Sponge community construction focuses more on vertical design. Green roofs, interception devices, high parterres, rain barrels, sunken green belt, permeable surface are integrated vertically so that rainfall would be absorbed level by level. The remaining rainfall partly infiltrates into soils, while the rest flows into bio-retention ponds or rain drainage system as runoff, and is further stored in rain pools or scenic ponds, then treated for watering and landscape water use, as well as road sprinkling. Sponge community construction also favors more green spaces in the plazas and parking lots, less impermeable pavements made of

concrete, asphalt, etc. The sponge community would become a low-temperature region for LID measures, which should help strengthen local air circulation and weaken the surrounding heat island effect. Another key aspect of sponge community is green space system construction, including "green planes" and "green lines." A green plane is a park or greenbelt of considerable area, of which the surface storage capacity can be increased by sunken greenbelt construction. While green lines mainly include non-motorized traffic system (pavements, bikeways, multifunctional non-motorized roads, etc.). By remoulding non-motorized roads into permeable surfaces, and connecting them to green spaces in buffer zone, an urban "green web" could be built to filter first flush pollution and reduce runoff peak volume. So far, Xiamen

has finished 5 green lines and is constructing 2 more. According to the plan, Xiamen's per capita green area ought to exceed 12 m² during 2014-2016. During 2017-2020, the city's green space system structure should be generally formed. The per capita green area should surpass 15 m² by 2020.

Sponge road construction refers to transform roads and greenbelts into sponge constructions. The primary is slope landscaping and ground slope aspect design. Curbs are lessened to only necessity, and designed to be no higher than the road, avoiding blocking the rainwater. Greenbelts along roads are combined with sunken greenbelt, bio-retention infrastructures, grassed swales and so on, while larger green spaces, such as traffic islands and flyover surroundings, are altered to rain gardens, rain water wetlands, ponds, regulation pools or sunken green spaces. Runoff over pavements is drained through underground sewers into storage devices in greenbelts.

Ecological river system construction

Ecological river system construction includes recovering water body damaged by landfill, river dredging, altering river morphology, and resuming aquatic ecological conditions, biomes, and ecological functions. By far Xiamen has initiated ecological recovery projects for 10

ivers (Guoyun Stream, Shengqing Stream, Yaoshan Stream, Hou Stream, Guanxun Stream, Daitou Stream, Dongxi Stream, Longdong Stream, Jiuxi Stream and Xiangan Ecological Rivers) and 3 lakes (Yundang Lake, Maluan Bay and the Nose Canal). Engineering measures adopted includes ecological embankment (natural slope revetment, stone-mesh revetment, vegetated block slope protection, ecological geofabriform revetment), riverbank buffers (tree belts or grassland built along riverbanks and valleys), river dredging, and ecological water supplementation with rain water or recycled water. In the Xiang'an ecological water replenishment project, stored rain water and recycled water are pumped to a scenic lake with high elevation by solar PV power, and then flow into streams by gravity. In this way, the system is able to replenish river system automatically in sunny days, and stop in rainy days when rivers are supplemented by rainfall; in a word, the system is complementary with weather.

Pollution control

Xiamen is suffering from severe water pollution induced by wastewater discharge, non-point source pollution of runoff, and waste dumping along rivers. The sponge city project applies interception infrastructures and ecological restoration techniques to solve the problem.

Figure 2. Stone-mesh revetment



Figure 3. Vegetated block slope protection



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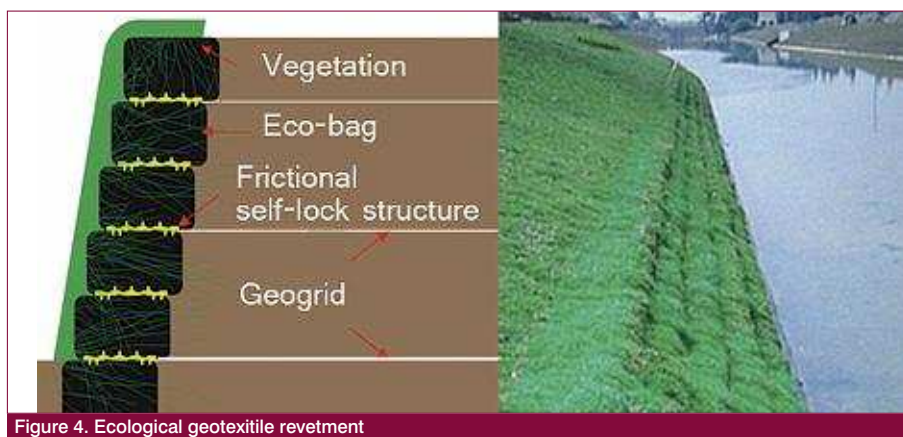


Figure 4. Ecological geotextile revetment

To control point-source pollution, rain-sewage separated sewers are built and wastewater treatment plants are extended. For regions not reached by the sewer system yet, distributed wastewater treatment plants are built to control wastewater discharges. Non-point source pollution is reduced by constructing green roofs, rain barrels, permeable pavements, plant filters, grassed swales, infiltration swales, sand filters, bio-retention pools and other similar features. Ecological floating beds, which consume nitrogen and phosphorus, are set in rivers and lakes, to purify eutrophic waters and restrain overgrowth of planktonic algae.

Waterfalls, fountains, jet currents, and other methods are adopted to increase dissolved oxygen. In the open area of lake entrances, artificial wetlands are built to purify entering water. Sediments of closed- and semi-closed lakes are cleaned regularly. Rubbish recycling is controlled more strictly, so that any waste is forbidden into river-lake systems. Measures as above would alleviate urban water pollution as well as improve the urban landscape and living environment.

Waterlogging prevention construction

Waterlogging prevention construction consists



Figure 5. Installation site of one of the distributed wastewater treatment devices

of rain-sewage diversion projects, flood discharge trenches and open channels extension, and the installation of additional drainage pumps in waterlogged lowlands. Presently projects under construction include 2 large pumping stations (Yundang Lake drainage pumping station and Xinglin Bay drainage pumping station), and 44 drainage infrastructures on sites that are particularly prone to waterlogging. Moreover, the rain-sewage diversion project of Haicang District is in the planning phase at present, planned to be completed by 2020.

Lessons for sponge city construction in Xiamen

One of the most prominent issues that Xiamen's sponge city construction faces is water pollution. To solve this problem Xiamen explores 3 distinct engineering methods:

(1) Distributed wastewater treatment devices

Due to the high cost and long duration of drainage system construction in some recently built-up regions, Xiamen applies distributed wastewater treatment devices (such as High Fiber Reinforced Plastic Tank (HFRPT) for

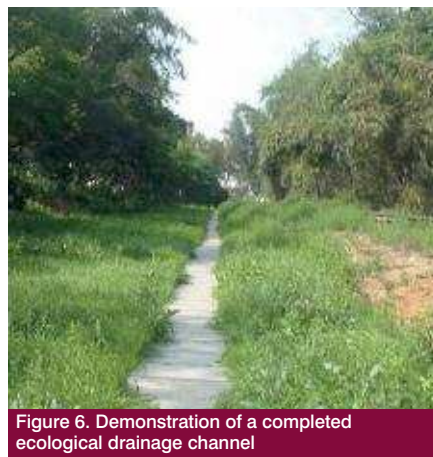


Figure 6. Demonstration of a completed ecological drainage channel

digestion). This solution overcomes difficulties of collection, discharge, treatment and recycling in traditional centralized wastewater treatment methods. It costs less, gathers wastewater more efficiently and reuses recycled water more conveniently. Also the devices fit right into surroundings, requiring little ground construction area and less gathering-delivery sewers, producing no outlet discharges or pollution.

(2) Ecological drainage channels renovation

To reduce water pollution, drainers are installed underneath flood-drainage channels to collect wastewater, which is then conveyed to the nearest underground wastewater treatment devices through sewers, and diverted to the surrounding water body after having been treated to Class IV in the national surface water quality standard. On the channel beds, suitable plants are planted, so that flood flowing would be unaffected in rainy seasons while the landscape is more appealing in dry seasons.

(3) Comprehensive management in the Nose Canal

The Nose Canal is in the mid-north region in Xiamen Island. Presently, the canal is almost a culvert. Backwash water from nearby water plants and domestic wastewater from in-city villages are discharged directly into the canal, forcing the natural waterway into local waste drainage channel. To improve local water quality, local government has initiated a comprehensive management project into the sponge city construction. Firstly, a sewage intercepting pump station is constructed to manage the first flush pollution. Then the culvert stretches are transformed into open canals, ensuring the flood discharge capacity of the canal. Meanwhile, the ecological functions of the canal are restored to ensure living conditions of fishes, amphibians and birds. Landscape design is also valued in the project. Elevation differences are managed with waterfalls. Banks are built into gentle slopes, and pavements or recreation spaces are built along.

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