

## Application Status and Development Suggestions of Sponge City Pervious Concrete

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**Abstract:** Sponge City means that certain properties of the city can be better than the sponges, and can adapt to changes caused by changes in the external environment. It has certain adaptability indicators for disaster prevention and mitigation. Through the optimized design of the city, the city's utilization of water sources in the drought and flood seasons has been further improved. The sponge city is built on the principle of harmonious coexistence between man and nature. Under the premise of ensuring urban flood control and drought prevention, the accumulation, penetration and purification of rainwater in urban areas are greatly realized, and the utilization of rainwater resources and ecological environment protection are promoted. In this paper, through the research on the application status of key permeable concrete in sponge city, this paper proposes the development of the next permeable city pavement of sponge city.

### 1. Permeable Performance Requirements of Sponge City Permeable Pavement

#### 1.1. Permeability Coefficient

The water permeability coefficient is also called hydraulic conductivity. In an isotropic medium, it is defined as the unit flow rate per unit hydraulic gradient, indicating the ease with which the fluid passes through the pore skeleton.

The expression is:

$$\kappa = \frac{k\rho g}{\eta} \quad (1)$$

Where  $k$  is the permeability of the porous medium, which is only related to the nature of the solid skeleton,  $\kappa$  is the permeability coefficient,  $\eta$  is the dynamic viscosity coefficient,  $\rho$  is the fluid density,  $g$  is the gravity acceleration.

In anisotropic media, the permeability coefficient is expressed in tensor form. The larger the permeability coefficient, the stronger the water permeability of the rock. The permeability coefficient of the strong permeable coarse gravel layer is  $>10$  m/day and night; the permeability coefficient of the weakly permeable subsoil is 1 to 0.01 m/day and night; the permeability of the impervious clay is  $<0.001$  m/day and night. According to this, the soil permeability coefficient is determined by the soil texture.

Water permeability and compressive strength are the most important properties of permeable concrete, and they are contradictory.

The effective porosity was used to characterize the water permeability. The relationship between compressive strength and effective porosity was studied by Zheng Mulian and others from Chang'an University [7]. The correlation coefficient was  $R=0.8631$ :

$$f_{c,7} = -0.3806n_e + 17.058 \quad (2)$$

Where  $f_{c,7}$  is 7d compressive strength,  $n_e$  is effective porosity.

It can be seen that there is a good linear relationship between the compressive strength of the permeable concrete and the porosity. This is of great significance for the design optimization and theoretical calculation of the mix ratio of permeable concrete.

## 1.2. Factors Affecting the Permeability Coefficient

The factors affecting the water permeability coefficient of road dressings in sponge city mainly include porosity, adhesive strength and aggregate particle size.

Porosity is the main factor affecting the strength of permeable dressings. In engineering applications, road dressings should also have sufficient strength in the case of certain water permeability. The effective porosity is generally maintained at 15% to 25% to meet the permeation performance required for permeable roads.

According to Bai Xiaohui et al., the factors affecting the porosity of permeable concrete and the relationship between porosity and permeability coefficient of permeable concrete were studied [3]. As shown in Figure 1-2, the porosity is between 16.2% and 19.8%, and the relationship between the aggregate size, permeability coefficient and porosity is analyzed. Thus, the permeable concrete with smaller particles is obtained. Because the connection of the pores is relatively small, the water permeability is small, but the water cannot flow out, and even the pores of the permeable concrete are blocked.

Table 1 Mix ratio.

	Aggregate size/mm	Aggregate/kg	Cement/kg	Water/kg
1	2.5-5	62.7	17.97	5.37
2	5-10	61.38	17.54	5.26
3	10-15	60.06	17.16	5.15

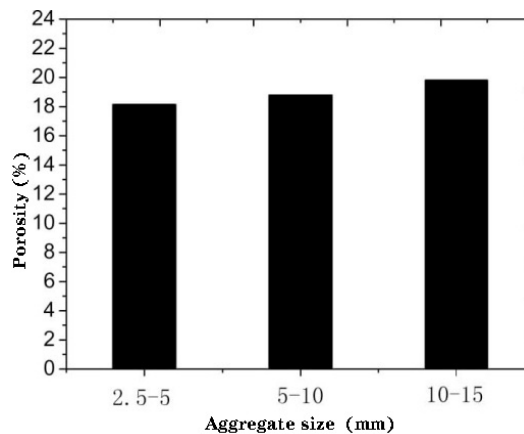


Figure 1 Porosity of permeable concrete with different aggregate sizes.

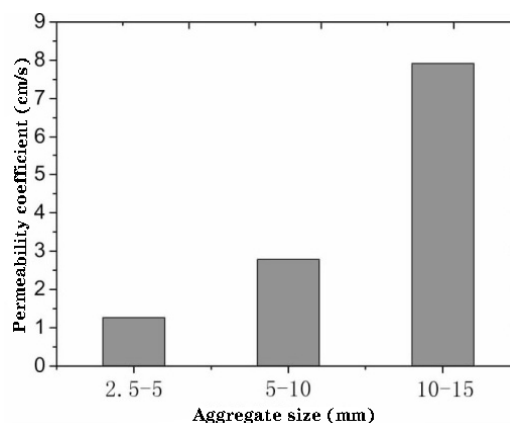


Figure 2 Permeability coefficient of permeable concrete with different aggregate sizes.

### 1.3. Research and Application of Existing Permeable Concrete

Since the beginning of this century, China has begun to promote the use of permeable concrete.

In 2004, five demonstration areas in Beijing used the method of laying permeable concrete roads to collect municipal roads, community greening and rainwater in the exhibition center for household flushing, plaza fountains and groundwater recharge, which effectively utilized in heavy rain. Rain water resources, reduce the pressure of urban sidewalk parking lot flooding.

In 2008, the area of permeable concrete in the Olympic buildings and concrete was about 117,000 m<sup>2</sup>. The rainwater passing through the permeable concrete fountain is discharged into the track by means of setting intercepting ditch around the track to realize the use of rainwater in the stadium. The average annual use of rainwater is about 120,000 m<sup>3</sup>, and the rainwater utilization rate is about 85%, saving the game. Road hydration. It can be said that permeable concrete has been successfully applied in Beijing.

Shanghai has actively promoted the application of permeable concrete in new and renovated drainage. In 2010, more than 60% of the pavements in the Expo site were made of permeable concrete, such as Expo Center Plaza, Expo Park, Expo Park Floor and Africa Square. After repeated rainfall monitoring, the rainwater can quickly penetrate into the ground, there is no water on the road surface, and no reflection at night, which increases the safety and comfort of road traffic. At the same time, it suppresses the urban “heat island effect”.

In the first cover horticultural exposition project in 2011, Guangxi adopted a permeable concrete pavement, and the paving site was a waterfront courtyard system garden pool. When the paving system works, the water that falls back can be returned to the pool through the high-permeability concrete cover plate in an instant, without the overflowing water overflow phenomenon, which increases the beauty and ornamental of the garden and achieves the expected design effect.

In addition, in other cities in China, permeable concrete has also been widely used. Nanjing built the first permeable concrete plaza on the Shofu West Road. The 300m long river channel was all paved with permeable concrete. Hangzhou Jinzhuang Park built the first resin permeable park, which has good anti-skid performance and can also play a good role in heat absorption and cooling.

In 2009, Xi'an Daming Palace National Heritage Park Yudao Square was covered with a large area of permeable pavement, with an area of 150,000 m<sup>2</sup>, and achieved good results.

However, the problems in the development of permeable concrete:

- 1) Although the water-permeable concrete has good water permeability, the mechanical properties have decreased.
- 2) As the use time is extended, the water permeability and drainage performance of the permeable concrete will gradually decrease.
- 3) The permeable concrete has better freeze-thaw resistance than ordinary concrete.
- 4) At present, the cost of permeable concrete is slightly higher than that of ordinary concrete.
- 5) China has not yet developed design specifications, standards and construction technical regulations for permeable concrete, which adversely affect the manufacture and construction supervision of permeable concrete.

### 1.4. Recommendations for Water Permeability of Permeable Roads

(1) Systematic research on the microscopic and macroscopic structure of permeable concrete materials, further explaining its performance and physical and mechanical properties to improve the compressive strength, flexural strength and durability of permeable concrete.

(2) Analyze the causes and influencing factors of the permeable function of permeable concrete, study the corresponding solutions and analyze its feasibility.

(3) Conduct on-site experimental research on the eco-environmental indicators of permeable concrete in terms of ventilation, water permeability, sound absorption and noise reduction, and purification of water bodies, in order to expand its application in the field of ecological protection.

(4) Formulate national-level normative standards for the design, construction, maintenance and management of permeable concrete mix ratio. In order to promote the application nationwide.

## 2. Sponge City Water Storage Performance

### 2.1. Sponge City Water Storage

The research shows that the technical standards of the sponge city are not uniform, and the measures are numerous, which is not conducive to the spread and popularization. Therefore, in this paper, we classify the rainwater in the sponge city into three categories. The permeable concrete involved in the above is used to collect rainwater. The “water collection measures” are used for “water storage measures” to store, store and filter rainwater, and “water use measures” for effective use of rainwater [1]. The water storage measures for the sponge city will be explained below.



Figure 3 Sponge City Diagram.

### 2.2. Current Research Results of Water Storage

(1) Design of underground reservoirs based on the concept of sponge city. In the process of collecting the rainwater pool, it generally consists of eight parts, including the pool body, the sediment well, the water well, the high and low ventilation caps, the inlet and outlet water pipes, the aeration system and the overflow pipe. The treatment of aquifers should be differentiated according to the choice of plants [8].



Figure 4 Underground storage tank rainwater storage system explanatory diagram.

(2) Rainwater garden design, the marginal area is often set as grassland, and the rainwater runoff is firstly intercepted in the area, and then enters the buffer zone [5]. The buffer zone can be placed with fine stones to further filter the impurities in the rainwater and buffer the flow velocity. At the same time, as a dividing line, the plants in the buffer zone need a certain moisture resistance. In order to avoid the direct scouring of the plants caused by the rain, the rainwater is dissipated by gravel after passing through the abutment [2].



Figure 5 Rainwater garden design before and after comparison.

(3) Sinking green space has also been applied in the landscaping of some cities, and the effect is also remarkable. This kind of green space is to increase the storage volume by sinking the green space, and achieve the purpose of water storage and water purification. Generally, it is constructed into a wet pond, a wetland, and a biological detention facility [6].

### 3. Water Permeability and Water Storage Performance of Sponge City Permeable Pavement

The traditional road ground has basically no water permeability. Relying on road flooding and drainage pipe network drainage is the main way for urban flood control. However, with the continuous development of urbanization, the level of urban infrastructure construction is seriously lagging behind. Urban drainage facilities cannot effectively meet the urban drainage requirements. When heavy rains encountered, the accumulation and flooding of rainwater is very serious, which has caused a significant impact on urban flood control. The permeable pavement with good water permeability can effectively reduce the urban surface runoff coefficient, shorten the peak occurrence time, reduce the burden of drainage facilities, and reduce the flood control pressure of the city [4].

Sponge City mainly refers to the ability to resiliante natural disasters and environmental changes. It is like a sponge, it can absorb water, store water, seep water, clean water in rainfall. At the same time, the stored water can be effectively released. As mentioned above, the use of permeable concrete paving pavement is of great significance for alleviating the special weather floods of urban roads and promoting urban drainage pipelines. The use of an underground reservoir design, rainwater garden design and sunken green space design are of great help to the rainwater storage function. Thereby more powerful response to the phenomenon of urban water shortage.

### 4. Conclusion

“Sponge City” is currently a hot spot in urban management. The city should eventually be able to be as flexible as a sponge, that adapting to environmental changes and coping with natural disasters. Building a “sponge city” should follow the principle of ecological priority. It is of great importance to meet the water demand of specific areas by rational use of rainwater. Therefore, we should actively promote the construction of sponge cities in China, establish a long-term monitoring mechanism, find out the current situation and development trend, conduct dynamic supervision and continuous evaluation of the effectiveness of sponge city construction.

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