Experimental Study on Permeability of Concrete

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Abstract. To study the influencing factors on permeability of pervious concrete, by adding inorganic organic composite materials obtained experimental results show that different aggregate size, aggregate cement ratio of different, different water cement ratio on the permeability performance. The permeability of the concrete was tested by using the self-made permeable device. The experimental results showed that the permeation coefficient of the experiment was obtained and the factors influencing the permeability of the concrete were compared and analyzed. At the same time, the porosity of pervious concrete was measured, the influence of various variables on porosity was studied, and the influence of various factors on the permeability of voids was found. Finally, through comprehensive analysis of a variety of factors, the optimal water cement ratio is 0.28. At this time, the pervious performance of concrete is optimal.

1. Introduction
The city's hardened impervious surface has brought a serious "heat island effect" to the city, leading to frequent waterlogging in the rainstorm season, and the depletion of groundwater resources. On today's China, under the guidance of sustainable development, maintaining ecological balance and sponge city, ecological pervious concrete will be the main force of sponge city construction. The use of pervious concrete pavement can increase the city's water and breathable area, adjust the climate, reduce the surface temperature, ease the "heat island effect." This kind of ground takes full advantage of rain, snow and precipitation, and plays the role of "reservoir" of permeable subgrade.

Water permeability of concrete is believed as the key property related to the serviceability and durability of concrete structures subjected to aggressive environments, since water acts as either the major agent responsible for the deterioration of concrete or the transport medium for aggressive species like chloride or sulfate ions [1]. Many experts and scholars at home and abroad have studied the permeable concrete many years ago. Physical experiment has been exercised for many years to measure water permeability [2,3] and to investigate different variables affecting water transport in cementitious materials [4]. Among these variables are the water–cement ratio [5], aggregate content [6], aggregate size [7] and pore characteristics [8], etc. In particular, changes in the mixing ratio may have a considerable impact on the permeability of the concrete. In addition, a large number of specimens should be prepared and tested to eliminate the stochastic variations aforementioned.

Durability of concrete depends largely on its water permeability, which is dominated by the composition and difficulty evaluated. Based on the above background, based on the organic inorganic multi material composite technology, using Portland cement, silica fume and other materials, a high
permeable coefficient concrete for sponge city is developed. In the experiment, permeability coefficients of specimens with different aggregate volume fractions are measured. And based on Darcy's law, to develop a device that can accurately determine the permeability coefficient to determine the permeability of permeable concrete. In the experiment, the effect of aggregate particle size distribution and water glue ratio on the permeability of porous concrete was studied.

2. Material and permeability calculation method

2.1. Cement
Pervious concrete is a porous structure. Its strength mainly comes from the point of contact between the aggregate. Therefore, cement, which is an important component of cementitious material, has the strength grade, activity, variety and dosage as the key factor of permeable concrete strength, which directly affects the performance of permeable concrete. The chemical composition of the cement is given in Table 1. The physical and mechanical properties of cement specimens are listed in Table 2.

| Table 1. Components and mineral composition (%) of cement. |
| SiO₂ | Al₂O₃ | Fe₂O₃ | CaO | MgO | Loss on ignition | C₃S | C₂S | C₃A | C₄AF |
|---|---|---|---|---|---|---|---|---|---|
| 18.96 | 6.05 | 3.42 | 63.22 | 1.21 | 3.07 | 65.35 | 5.06 | 10.23 | 10.40 |

| Table 2. Physical and mechanical properties of cement specimens. |
| Specific surface area (m²/kg) | Setting time(min) | Compressive strength | Flexural strength (MPa) |
|---|---|---|---|
| | initial | Final | 3d | 28d | 3d | 28d |
| 362 | 140 | 245 | 38.7 | 55.8 | 7.2 | 10.6 |

2.2. Aggregate
Aggregate as the structural skeleton of pervious concrete, its type, surface shape, particle size and gradation influence the permeability of concrete directly. In order to ensure the performance of pervious concrete, coarse aggregate with larger particle size and single grading is usually chosen. In this experiment, the particle size is 4.75mm ~ 9.5mm, 9.5mm ~ 16mm and 16mm ~ 19.5mm and the needle-like particle content is less than 5%. Before the experiment, the stones are washed, and the mud content and mud content are basically zero. The physical indicators of aggregate are shown in Table 3.

| Table 3. The physical indicators of aggregate |
| Particle size(mm) | Apparent density (kg/m³) | Bulk density (kg/m³) | Porosity (%) | crushing index (%) |
|---|---|---|---|---|
| 4.75~9.5 | 2660 | 1499 | 43.6 | 2.1 |
| 9.5~16 | 2665 | 1470 | 44.8 | 2.3 |
| 16~19.5 | 2669 | 1445 | 46.3 | 2.4 |

2.3. Permeability calculation method
Pervious concrete is a multiphase structure with voids in it. Free water can easily penetrate through the voids of the concrete medium to achieve penetration effect. Because of its porous medium, water flows through the interstices of the structure and reaches the action of water seepage. Darcy’s classic law, or equation, states that the water flux q in one-dimensional flow is directly proportional to the driving hydraulic gradient i. Such as the following equations (1, 2, 3)

\[ Q = qt \] (1)
\[ q = A k i \]  
\[ i = \frac{h}{L} \]

Finally, the equation (4) is obtained by the above equation.

\[ k = \frac{QL}{hAt} \]  

Where the proportionality constant K is called the hydraulic conductivity of the porous medium or soil and is recognized as a composite property of both the porous medium (soil) and the flowing liquid (water). where A is the constant bulk cross-sectional area of the soil column and Q is the volumetric time(t) rate of water flow perpendicular to A. h is hydraulic heads and L is the height of the test block.

3. Specimen preparation
First, clean the aggregate 4.75mm-9.5mm (A), 9.5mm-16mm (B) and 16mm-19.5mm (C) with clean water. Then, the cementing material is added in proportion, and the concrete mixer is stirred. Finally, the 100mm ×100mm ×100mm mold is formed and divided into three layers of compaction. After molding, the sample is shown in Figure 1. Put the test pieces in the curing box and maintain the constant temperature and humidity maintenance. The permeability test is performed using the device, shown in Fig. 2, and the result is measured when the hydraulic heads is kept constant.

![Figure 1. Specimen](image1.png) ![Figure 2. Permeable device](image2.png)

4. Experimental results and analysis

4.1. Effect of Aggregate Particle Size on Permeability
In the experiment, the aggregate of A, B and C were used, and the permeation coefficient of the specimen increased with the increase of aggregate size under the same conditions. As shown in Figure 3, the relation of permeability coefficient, porosity and aggregate particle size at the same water cement ratio is shown.
The experimental results show that the aggregate size is larger, the porosity is bigger, and the water permeability is better. Mainly because of the coarse gap of the coarse aggregate specimen, under the same conditions, the coarse aggregate internal porosity is higher, so that its permeability coefficient is higher.

4.2. Effect of Water - cement Ratio on Permeability

In the process of forming specimens, serious segregation may occur due to the large amount of admixture or water ash. When the specimen is formed, it is possible to form a compact stone body at the bottom of the specimen due to segregation, which will have a great effect on the experimental results. When the experiment is in good condition, as shown in Figure 4, the permeability coefficient and porosity of specimens will increase with the increase of water cement ratio under the same conditions. But the porosity of specimens with relatively large water content is smaller than that of small water cement. Therefore, within a certain range, the permeability will become larger with the increase of water cement ratio.

4.3. Effect of the aggregate cement ratio on Permeability

Under the same conditions, the effect of the aggregate cement ratio on the permeability of concrete specimens will increase with the increase of the aggregate cement ratio, as shown in figure 5.
It can be seen from the diagram that the aggregate size has great influence on the permeability coefficient, and also have great influence on the porosity. The larger the aggregate size, the greater the influence of voids on the internal structure of the specimen. For example, at the same water cement ratio and the aggregate cement ratio, the porosity difference between the particle size C and the particle size B is about 0.8%, and the porosity of the particle size B and the particle size A is about 0.2%. The water permeability coefficient of particle size C is significantly higher than that of particle size A and particle size B, and the water permeability is obviously enhanced.

5. Conclusion

The permeability of pervious concrete depends on the size of the measured porosity. Generally, the larger the porosity is, the greater the permeability coefficient is, and the permeable pore is the communicating pore. Due to the increase of amount of cement, causes between the aggregate number and size of the original connected pores are reduced, and even block the pores, the pore is not connected, which leads the whole skeleton permeable channel is reduced, the permeability coefficient decreases. The cement paste has rheological properties, the increase of amount of cement will make porelike blocked probability increases, so the porosity and permeability coefficient of porous concrete with different cement content increased significantly. Under the same conditions, aggregate size, Water - cement Ratio and the aggregate cement ratio are important factors affecting the permeability of single size pervious concrete, and the influence of particle size and thickness on the permeability of concrete. Comprehensive analysis, aggregate particle size is the most influential factor in the permeability of concrete. Finally, through comprehensive analysis of a variety of factors, the optimal water cement ratio is 0.28.

Acknowledgments

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