Experimental Analysis and Study on the Effect of Glue Addition Rate on the Performance of Sponge City Permeable Brick

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Abstract. Sponge urban construction has become one of the heated topics in the fields of science and technology, and faces many disputes. There are different opinions and cognitions to the connotations, objectives, contents and effects of sponge urban construction. But investigating its foundation of sponge city is the basis of the permeable brick. The purpose of this test is to find the optimum mix ratio of permeable bricks, that is, to make them have good permeability on the premise of satisfying certain strength. Through experiments, aggregate cement ratio is fixed; water cement ratio and gluing ratio are adjusted. The conclusion is that the best mixing ratio is aggregate cement ratio 3.5, water cement ratio 0.38 and gluing ratio 2%, which is to meet the requirements of the sponge city for the compressive strength and permeability coefficient of single brick.

1. Introduction

Today's society is facing a variety of water crisis, water shortage, water pollution and other problems [1]. Permeable concrete, which aims to achieve air permeability, water permeability, to adjust ecological balance and protect the environment, is a new type of environmental protection concrete road material in recent 20 years. Compared with the traditional concrete, its biggest characteristic is that it has certain connecting pores, good water permeability and moisture retention, and its performance is close to that of lawn and soil ground. This kind of concrete is used to pave roads, squares and pedestrian roads, which plays an important role in regulating ecology and improving environment. However, the main reason for the current urban water problem is that the urban building and hardening area are too large, the vegetation coverage is too low or damaged, the water absorption and storage capacity of the city is poor, and the drainage capacity of the drainage facilities is insufficient, and the light pipe is rebuilt [2]. The purpose of this experiment is to explore the influence of water cement ratio and glue ratio on the strength and permeability coefficient of concrete permeable brick Image data analysis method is used to analyze the data and propose the optimal mix ratio parameters.

2. Mix Design and Test Method

The main purpose of pervious concrete is water permeability. As the pervious brick laid on the road and the park sidewalk, it must have certain strength. The strength of pervious brick, it is well known, is inversely proportional to the water permeability. That is, with the increase of water permeability, the strength gradually decreases. Therefore, it is required that pervious brick should have better water permeability under the premise of meeting its strength.
2.1. Selection of Raw Materials
Aggregate: the aggregate gradation is an important index to control the quality of pervious concrete, and is the structural framework of pervious concrete. The aggregate is divided into coarse aggregate and fine aggregate. The test shows that in order to ensure the due strength and good permeability of pervious concrete, the aggregate should adopt discontinuous single grain grading, and the coarse aggregate should adopt 5~10mm crushed stone, with the apparent density of 2.743mg/cm$^3$. The proportion of the fine aggregate used in this test is small, the diameter range is 0~5mm, and the apparent density of the fine aggregate is 2610mg/cm$^3$. The particle size test results used in this test are 0.075~9.5mm, and the mud content is 6.5%.

Cement: Portland cement or ordinary Portland cement above grade 32.5 is generally used for pervious concrete. As pervious concrete is a porous aggregate structure formed by cementation between coarse aggregate particles through a thin layer of hardened cement slurry, the force is transmitted through the cementation point between aggregates when stressed, so high-strength cement is generally selected. In this paper, 42.5 grade ordinary Portland cement is used. In addition, before using the cement, in addition to the manufacturer's certificate, the cement on site shall also be subject to routine tests such as strength setting time, stability, etc., and the cement can only be used after passing the inspection [3].

2.2. Mix Design
Referring to the research results of some scholars [4-8], through the change of reasonable mix proportion parameters, on the premise of ensuring that the surface of coarse aggregate is fully covered by cement slurry and make sure that there is enough connecting space between the coarse aggregate as far as possible, the concrete not only meets the requirements of certain strength, but also has good water permeability. In this experiment, aggregate cement ratio was 3.5; water cement ratio was 0.34, 0.36, 0.38, 0.40 and 0.42, respectively. 107 glue was used, and the glue adding rate was 0%, 1%, 2% and 3%, respectively.

2.3. Test Method
2.3.1. Strength Test Method. The test method is as the same as that of ordinary concrete, in which the specimen sizes of compressive strength test is 150mm×150mm×150mm. After curing for 7 days and 28 days under the same conditions, the test method of compressive strength and tensile strength of ordinary concrete “Standard for test methods of concrete physical and mechanical properties” (GB/T 50081—2019) is used, and the NYL-30 pressure tester is used for the determination of compressive strength.

2.3.2. Test Method of Water Permeability Coefficient. This test refers to “Technical specifications for pervious concrete pavement” (CJJ 134—2009) for pervious cement concrete pavement as the standard, and adopts cylinder test block with diameter of 100 mm and height of 50 mm. Before the test, measure the diameter (D) and thickness (L) of the cylindrical sample with a steel ruler twice, take the average value, accurate to 0.1cm, and calculate the surface area (A) of the sample. During the test, the block to be tested shall be immersed in water for 20 min. It shall be taken out and installed into the water permeability coefficient test device to connect and seal the block and the water permeability cylinder. Then put it into the overflow tank, open the water supply valve, and make the airless water enter the container. When there is water flowing out of the overflow hole of the overflow tank, adjust the water inflow to keep the water level of the permeable cylinder at a certain level (about 150 mm). When the water flow at the overflow port of the overflow tank and the overflow port of the permeable cylinder is stable, use the measuring cylinder to connect the water from the water outlet, record the water outflow in 5 minutes, measure 3 times, and take the average value. Finally, measure the difference (H) between the water level of the permeable cylinder and the water level of the overflow tank with a steel ruler to the nearest 0.1 cm. Measure the temperature (T) of the water in the overflow tank in the test with a
thermometer to the nearest 0.5°C. The permeability coefficient of permeable concrete can be obtained by substituting the above measured data into the calculation formula $K = Q \cdot L / (A \cdot H \cdot t)$ [9]. As the dynamic viscosity coefficient of water directly affects the size of the permeability coefficient, the higher the temperature is, the smaller the dynamic viscosity coefficient is, and the larger the permeability coefficient is. Therefore, the permeability coefficient should be converted to the standard temperature to be comparable.

3. Test Results and Analysis

3.1. Strength Test Results and Analysis

Through a large number of tests and strength test results, the compressive strength is shown in table 1 when the water cement ratio changes with different glue addition rate.

| Water cement ratio | Glue addition rate | 0%  | 1%  | 2%  | 3%  |
|--------------------|--------------------|-----|-----|-----|-----|
| 0.34               | 33.2               | 32.1| 30.3| 28.7|
| 0.36               | 35.1               | 34.0| 32.6| 30.1|
| 0.38               | 36.7               | 36.1| 35.8| 35.1|
| 0.40               | 39.2               | 37.3| 37.1| 36.0|
| 0.42               | 38.7               | 37.5| 36.6| 36.1|

According to the results in the table 1, the broken line diagram of the influence of the glue addition rate on the strength is shown in figure 1(a) and 1(b).

![Figure 1.](image)

According to the results in the table 1, the broken line diagram of the influence of the glue addition rate on the strength is shown in figure 1(a) and 1(b).

It can be seen from figure 1(a) that under the same glue addition rate, with the increase of water cement ratio, the compressive strength increases obviously, reaching the highest value when the water cement ratio is 0.40, and the water cement ratio decreases slightly. When the water cement ratio is 0.34, the test effect shows that the mixture is obviously dry; the stone cannot be completely wrapped by mortar, which has a great impact on the strength. After increasing the water cement ratio, the humidity is significantly increased, and it can be evenly wrapped when the water cement ratio is 0.36 and 0.38. When the water cement ratio is 0.40, a large number of redundant mortars appear. When the water cement ratio is 0.42, the surrounding of the test block is almost completely covered by mortar. From figure 1(b), under a certain water cement ratio, the compressive strength of concrete permeable brick shows a downward trend with the increase of glue addition rate. With the increase of glue addition rate, the cement is bound into blocks, and the bond with stones is affected to some extent, so the strength
shows a slight decrease trend. The defective products are shown in figure 2(a) and 2(b).

![Incomplete wrapping of mortar](image1)
![Excess mortar](image2)

**Figure 2.** Diagram of test defective products.

### 3.2. Water Permeability Test Results and Analysis

According to the test of water permeability, the water permeability coefficient under different water cement ratio is shown in table 2.

| Water cement ratio | Glue addition rate 0% | Glue addition rate 1% | Glue addition rate 2% | Glue addition rate 3% |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 0.34               | 0.35                  | 0.49                  | 0.53                  | 0.55                  |
| 0.36               | 0.67                  | 0.69                  | 0.77                  | 0.82                  |
| 0.38               | 0.83                  | 0.92                  | 0.94                  | 0.99                  |
| 0.40               | 0.32                  | 0.40                  | 0.55                  | 0.63                  |
| 0.42               | 0.03                  | 0.08                  | 0.10                  | 0.12                  |

The line chart drawn from table 2 is shown in figure 3(a) and 3(b).

![Change trend chart of water permeability coefficient with water cement ratio](image3a)
![Change trend chart of water permeability coefficient with glue addition rate](image3b)

**Figure 3.** Change trend chart of water permeability coefficient with water cement ratio

From figure 3(a), the water permeability coefficient increases slightly with the increase of glue addition rate. When the adding rate is 0%, the water permeability is the worst, and it reaches the
highest when the adding rate is 3%. With the increase of glue addition rate, although the cement is more polymerized, the combination with the stone is reduced, and the strength shows a trend of decreasing. Due to the increase of the adhesion with the cement, the internal void of the test block becomes larger, so the water permeability is significantly improved.

It can be seen from figure 3(b) that with a certain glue addition rate, the water cement ratio ranges from 0.34 to 0.42, and the water permeability first increases and then decreases with the increase of water cement ratio. When the water cement ratio is 0.38, the water cement ratio reaches the peak, and then decreases abruptly. At this time, a large number of cement slurry is the most critical factor affecting the water permeability.

When the compressive strength is qualified, the test block effect with good water permeability is shown in figure 4(a) and 4(b). Obvious voids can be seen, and the connection between stones is good, so the strength can be guaranteed and the water permeability requirements can be met.

![Figure 4. finished product with good test.](image)

4. Conclusions
In the test, with the increase of water cement ratio, the aggregate is more fully wrapped by cement slurry, and more slurry can increase the compressive strength, so the compressive strength shows an upward trend. However, considering the water permeability, when the water cement ratio is 0.40, the water permeability suddenly decreases, and when the water cement ratio continues to increase, the water cement ratio is almost zero, so when the water cement ratio is 0.38, it is the optimal water cement ratio. With the increase of glue adding rate, the strength shows a slight decrease trend, but the water permeability is greatly improved. Considering that the purpose of this test is intended to be used on sidewalks such as park roadside and other sidewalks, there is a certain trade-off between the strength and water permeability. On the premise of meeting certain strength, the water permeability is improved as much as possible. In the process of change of glue adding rate from 2% to 3%, the compressive strength is reduced. The degree is slightly greater than the increase degree of water permeability, so the optimal glue addition rate is 2%. That is to say, the final conclusion of the test is: when the bone ash ratio is 3.5, the water cement ratio is 0.38, and the glue addition rate is 2%, it is the optimal mix ratio. At this time, the compressive strength is 35.8 mpa, and the water permeability coefficient is 0.94cm/s, which meets the requirements that the compressive strength of a single brick is not less than 31mpa, and the water permeability coefficient is not less than 0.1 cm/s.

In recent years, China's construction industry has entered a stage of rapid development. Due to the
traditional concrete production cannot meet the daily life of precipitation treatment, also cannot meet the requirements of sustainable development of society and economy. Pervious brick applied to sidewalk can ensure that the pavement is free of water and easy to melt snow. This can not only effectively reduce the inconvenience caused by water to pedestrians, but also play an important role in reducing noise and noise. The concrete pervious brick studied in this experiment both meets certain strength and has good permeability. The research on concrete pervious brick is still in its infancy, and a lot of research and development work is needed [10].

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