The study of pervious concrete mix proportion by the method of specific surface area of aggregate

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Abstract: The purpose of this paper is to solve the shortcoming of the mix proportion of pervious concrete. So we have done the research on the measurement of the specific surface area of aggregate, and the research on the volume change of cement after hydration, and the research on the best water-binder ratio and thickness of gelled material package. The experimental results show that the equivalent method is more accurate for measuring the specific surface area of aggregate. It can better reflect the specific surface area of aggregate. Moreover, the calculation method of the mix proportion of the cementing material can improve the utilization ratio of material and the quality of pervious concrete.

1. Introduction
Pervious concrete is a new type product of concrete which integrates the outstanding mechanical properties and water permeability of concrete. This kind of concrete products is also successfully used in the design and construction of various buildings with the development of the sponge city and the city greening. But we need pervious concrete to meet the requirements of permeability and mechanical properties. If we still take the absolute volume method, and the filling theory and volume method of CJJ/T135-2009 technical specification for pervious concrete calculation, there will appear many problems in practical application, such as excessive cement coating, the cement content is too small and the coating layer is too thin, too much water cement ratio leads to excessive flow of products and a series of problems such as water binder ratio is too small to be molded. In view of this kind of problem, this article will take the cementing material package thickness as the breakthrough point, carries on the correlation research of the pervious concrete mix. The goal of our experiment is to achieve the optimizing ratio of pervious concrete and improve the utilization ratio of materials.

2. The materias and test methods

2.1 The main raw material
(1) Cement: adopt the cement of ordinary Portland cement, and it has the strength grade of 42.5. As shown in table 1.

(2) Aggregate: The aggregate is selected according to the standard of aggregate for the ordinary concrete, and the size is 10-20mm of aggregate.

(3) Water: tap water.
Table 1: Physical and mechanical properties of cement

| Cement type | Normal consistency % | Density g/cm³ | Specific surface area m²/kg | Setting time/min | Breaking strength/MPa | Compressive strength/MPa |
|-------------|-----------------------|---------------|-----------------------------|------------------|-----------------------|--------------------------|
| P▪O4 2.5    | 27.0      | 3.15          | 350                         | 240              | 300                   | 5.2                      |
|             |          |               |                             |                  | 8.4                   | 26.1                     |
|             |          |               |                             |                  | 47.0                  |

2.2 Test method
Measurement of specific surface area of aggregate: First of all, made the standard sample is of cement mortar, make the standard sample block with cement mortar, in this experiment, the diameter of the standard test block is 16mm, the cylinder height is 10.5mm (Figure 1). And then take a certain quality aggregate, and we take it have a surface treatment with three standard test blocks at the same time, make the aggregate and the surface of the reference block with the same properties. Weighing the standard block and aggregate respectively after the surface dry. The standard block and aggregate were treated with paraffin wax (Figure 2). Weigh the wrapped aggregates and standard blocks. The formula is shown as (1).

\[
A = \frac{(M_{22} - M_{21}) \times S_1 \times n}{(M_{21} \times (M_{12} - M_{11}))}
\]

(1)

A is the specific surface area of aggregate (cm²/g); n is the number of standard test pieces; S1 is the surface area of a standard test block; M11 weight for standard block; M21 is the weight of aggregate; M12 the weight of the standard block after the package; M22 is the weight of the wrapped aggregate.

The volume of cement hydration was measured by liquid discharge method. Each experiment using cement 165g, and the water binder ratio was 0.25, 0.30, 0.40, and 0.50 respectively. Before the measurement, we have to water the cement block for 24 hours. After taking it out from the water, wiping the surface of the test block without water, and then start the test.

3. The test results and discussion

3.1 Aggregate ratio surface area measurement
According to the above test method, experimental data are shown in table 2, the picture of sample after coated is shown in figure 2.

The average value is 4.2426cm²/g of the specific surface area of the aggregate measured by the method described in this paper. The result is 1.52cm²/g by the equivalent sphere method. And when this value is used to calculate the porous concrete and try mixing, it is found that the amount of cementing material is too little, and it is difficult to wrap the aggregate particles well. The comparison shows that there is a big difference between the estimated method and the measured one. Therefore,
the actual measurement method is more conducive to accurate calculation, and it could greatly reduce the error in the calculation of mixing ratio.

Table 2: The measurements of aggregate specific surface area

| Number | \(M_{11}\) | \(M_{12}\) | \(M_{21}\) | \(M_{22}\) | \(S\) |
|--------|-----------|-----------|-----------|-----------|------|
| B1     | 12.9444   | 13.0579   | 101.1508  | 102.5849  | 4.1968 |
| B2     | 12.7984   | 12.9140   | 100.0023  | 101.7566  | 4.2313 |
| B3     | 12.8862   | 13.0020   | 98.2242   | 99.9782   | 4.2997 |

3.2 Volume change of cement after hydration

In the experiment, the amount of cementing material is 165g, and the water binder ratio is 0.25, 0.30, 0.40, 0.50, the results of the experimental volume measurement were shown in table 3.

According to the actual situation of the test, as well as the requirements of the cement paste when the concrete is mixed with water, when the water cement ratio is 0.50, the fluidity of cement slurry is too large, it is difficult to form a stable coating layer on the aggregate surface. Therefore, we use the water-binder ratio of 0.25, 0.30, 0.40 of the cement hydration volume change curve fitting, fitting results as shown in (2).

\[
V = -200A^2 + 352A + 242.7
\]

(2)

V is the volume of water binder ratio of A; A is water binder ratio.

Table 3: Volume change after the cement hydration

| W/C     | 0.25 | 0.30 | 0.40 | 0.50 |
|---------|------|------|------|------|
| Volume (\(\text{cm}^3\)) | 105  | 109  | 116  | 136  |

3.3 Different package thickness strength test

When the thickness of the coating is 0.25mm, 0.30mm, 0.35mm, 0.40mm, the cement volume is 167cm\(^3\), 200.4cm\(^3\), 233.8cm\(^3\), 267.2cm\(^3\) respectively, the amount of cementing material under different water binder ratio was obtained by the formula (2), the ratio and strength of pervious concrete with different aggregate thickness is shown in table 4, group A1-A3 package thickness is 0.25mm, group A4-A6 package thickness is 0.3mm, group A7-A9 package thickness is 0.35mm, group A10-A12 package thickness is 0.40mm, and the water cement ratio of A1, A4, A7, A10 is 0.28, the water cement ratio of A2, A5, A7, A11 is 0.3, the water cement ratio of A3, A6, A9, A12 is 0.32, the macroscopic characteristics of the concrete block after curing are shown in figure 3. Corner defects as shown in figure 4. The measurement results of pervious concrete porosity are shown in table 5. And the compressive strength is for 7d.

Table 4: The ratio and strength of pervious concrete with different aggregate thickness

| Serial number | Thickness (mm) | W/C | Cement (g) | Aggregate (g) | Water (g) | Strength (MPa) |
|---------------|---------------|-----|------------|--------------|-----------|----------------|
| A1            | 0.25          | 0.28| 256.5      | 1600         | 72        | 1.1            |
| A2            | 0.25          | 0.30| 253.4      | 1600         | 76        | 3.7            |
| A3            | 0.25          | 0.32| 249.9      | 1600         | 80        | 4.3            |
| A4            | 0.3           | 0.28| 307.7      | 1600         | 87        | 3.1            |
| A5            | 0.3           | 0.30| 303.4      | 1600         | 91        | 4.1            |
| A6            | 0.3           | 0.32| 299.2      | 1600         | 96        | 3.7            |
| A7            | 0.35          | 0.28| 359.8      | 1600         | 101       | 1.8            |
| A8            | 0.35          | 0.30| 353.9      | 1600         | 106       | 5.3            |
| A9            | 0.35          | 0.32| 349.1      | 1600         | 112       | 4.3            |
| A10           | 0.4           | 0.28| 410.3      | 1600         | 115       | 3.5            |
| A11           | 0.4           | 0.30| 404.4      | 1600         | 121       | 6.2            |
| A12           | 0.4           | 0.32| 398.9      | 1600         | 128       | 5.0            |
Figure 3: The macroscopic characteristics

Figure 4: Corner defects

Figure 5: The measurement results of pervious concrete porosity

Table 5: The open porosity

| Serial number | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | A10 | A11 | A12 |
|---------------|----|----|----|----|----|----|----|----|----|-----|-----|-----|
| Porosity (%)  | 28.1 | 26.6 | 29.4 | 27.5 | 28.0 | 26.0 | 28.0 | 26.6 | 26.8 | 26.0 | 23.8 | 25.0 |
| Average value | 28.0 | 27.1 | 27.1 | 24.9 |      |      |      |      |      |      |      |      |
According to figure 3, we can find that under the condition of the same thickness of the package, the flow phenomenon of cementing gradually appear with the increase of water cement ratio, such as A1-A3. Under the condition of the same water cement ratio, the aggregate surface slurry flow phenomenon also increased with the increase of the package thickness, such as A3, A6, A9, A12. According to figure 4, it can be found that the A1, A4, A7, A10 block has a lack of angle when the water binder ratio is 0.28, and the phenomenon of the lack of angle is gradually improved with the increase of the thickness of the package. According to figure 5, the compressive strength of pervious concrete increases with the increase of the thickness of the coating, but the porosity decreases gradually, and the compressive strength is higher when the water binder ratio is 0.30. According to figure 3 and table 5, the pervious concrete has high porosity and strength when the coating thickness is 0.3 or 0.35mm, ineffective cement particles were rarely produced similar to the A10. Through the above analysis, we can find that when the cement thickness is 0.30-0.35mm, the water to cement ratio is 0.30, the pervious concrete has better compressive strength, open porosity and higher utilization ratio of cementing material.

4. Conclusion
According to the research on the measurement of the specific surface area of aggregate, and the research on the volume change of cement after hydration, and the research on the best water-binder ratio and thickness of gelled material package, it can be found that there are still some errors in the measurement method of aggregate surface area. However, it is more accurate than the estimation method; at the same time, it can be found that the concrete block does not have slurry flow and too many ineffective cement particles obviously. Therefore, the specific surface area method of concrete mix design has a certain rationality and practicality. Therefore, the specific surface area method is reasonable and practical.

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