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A Comprehensive Review on Water Permeability Testing and Sealing Techniques in Concrete Construction

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The durability of concrete is determined by the permeability resistance to a large extent. The permeability resistance of concrete is an important index of concrete durability. This paper introduces the water permeability test process of concrete in China, Europe and the United States, and explains the sealing method of specimens in the water permeability test of concrete according to the Chinese standard, so that the construction inspection industry personnel can choose according to the actual situation of the project and the evaluation needs.

Keywords: Concrete; concrete impermeability; water permeability test; sealing method; comparison of impermeability methods.

1. INTRODUCTION

Concrete is the most widely used building material in the world today because of its versatility and relatively low cost, and is widely used in bridges, dams, highways, industrial and civil buildings and other structures. However, concrete is prone to erosion under natural environments such as surface wear, cracking caused by salt crystallization in pores, and

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exposure to extreme temperature environments such as freezing or fire, which leads to the decline of durability and reliability of concrete structures. The permeability of concrete refers to the ability of gas, liquid or ion to penetrate, diffuse or migrate in concrete under pressure, chemical potential or electric field force. The permeability of concrete refers to the ability of concrete to resist penetration, and the permeability of concrete is an important indicator of the durability of concrete. Therefore, the exploration of the permeability of concrete is also deepening. There are many existing methods to test the permeability of concrete. This paper summarizes the test methods of concrete water resistance according to Chinese and European national standards and the sealing method of specimens according to Chinese standards. Selecting appropriate test methods for different scenarios and testers' needs is more conducive to reflecting the true situation of concrete water resistance.

2. MECHANISM OF CONCRETE IMPERMEABLE

Concrete is made of course and fine aggregate, cementitious materials, water and additives in accordance with the appropriate proportion, after even mixing, molding and curing hardening of artificial stone, its essence is a heterogeneous, porous composite material [1]. In the construction process, in order to ensure the concrete and easy, mixing concrete when adding water will exceed the water required for cement hydration, and the excess water in the cement hydration will gradually evaporate, after the evaporation of water will leave many holes in the interior of the concrete, these holes may be connected into a pore, and cement hydration condensation will occur chemical shrinkage, which will also produce a hole in the hardened cement stone; and due to the concrete molding vibration is not real and other reasons cause honeycomb, holes and other defects will cause concrete water seepage, seriously affect its permeability. The permeability of concrete depends on these internal pores, water and erosive media can be infiltrated into the interior of the concrete through the internal pores from the outside to the inside [2]. In general, the number of holes in the interior of the concrete is less, the radius of the hole is smaller, the path of the hole is more tortuous, the permeability of concrete is better, the water and erosive media is more difficult to enter the interior of the concrete, the ability of concrete to resist external erosion is stronger, and the durability of concrete is better.

3. WATER PERMEABILITY TEST METHOD OF CONCRETE

3.1 China Standards

Concrete impermeability test is widely used in construction and water conservancy fields in China. For some hydraulic buildings and building parts with waterproof requirements, the water permeability resistance of the concrete used is a very important material technical index. The standards that specify the test methods for concrete impermeability include: Test method for long-term performance and durability of ordinary Concrete (GB/T50082-2009) [3], Test Procedure for Cement Concrete for Highway Engineering JTJ270-98 [4], Test Procedure for Concrete for Water Transport Engineering JTJ053-94 [5], Test Procedure for Hydraulic Concrete DL/T5150-2001 [6], etc. The principles of the above concrete impermeability test methods are basically the same, and the Darcy formula which has been developed in the 19th century is used to calculate the permeability of concrete [7]. It can be broadly divided into three categories:

3.1.1 Seepage height method

A group of 6 round table-shaped specimens with a size of 175mm×185mm×150mm were used for the test pieces, which were pressurized to 1.2MPa at one time and split after 24 hours at constant pressure. The arithmetic average of the water seepage height at 10 measuring points was used as the water seepage height of the test piece. Then the arithmetic average of the water seepage height of the 6 specimens was calculated as the average water seepage height of the group of specimens. According to the seepage height of the test site, the compactness of concrete is relatively compared. The seepage height method is suitable for concrete with high permeability resistance.

3.1.2 Relative permeability coefficient method

The seepage height method reflects the absorbed water and permeated water of concrete. The permeability coefficient is calculated through the seepage height and time, and the arithmetic average of the permeability coefficient of a group of six specimens is taken as the test result of the permeability coefficient.

The relative permeability coefficient is calculated according to formula (1):

$$K_r = \frac{aD_m^2}{2TH} \quad (1)$$

In the equation :K_r — relative permeability coefficient （mm/h）;D_m — Average seepage height（mm）;H — water pressure, expressed by the height of the water column (mm); T — constant pressure time (h); a — Water absorption of concrete (%), generally 0.03.

3.1.3 step by step pressure method

A group of 6 round table-shaped specimens with specifications of 175mm×185mm×150mm were used for the test. The test was started by applying 0.1MPa water pressure from the bottom of the specimen, and the water pressure was increased by 0.1MPa every 8h until the maximum water pressure when water seepage was found in 3 of the 6 specimens was used to calculate the impermeability label of concrete. Its impermeability label is calculated according to formula (2):

$$P=10H-1 \quad (2)$$

In the equation: P — impermeability grade of concrete; H — Water pressure (MPa) at the beginning of water seepage on the top surface of the third specimen.

Concrete impermeability grade is P2, P4, P6, P8, P10, P12, etc. The advantage of the impermeable labeling method is simple and intuitive. The anti-seepage marking method is more suitable for concrete with strength grade below C30, and the test results are similar for concrete with strength grade above C30, so it is not suitable for longer age and high-performance concrete.

3.2 European National Standards

3.2.1 Nordic national standard

According to the standard [8], at least 4 cylindrical specimens with a diameter of 100mm and a thickness of 20mm were prepared in the test. After 28 days of curing, the cylinder specimen was embedded in epoxy resin and the two ends were cut flat, and the sample was dried in an oven at 40℃ and constant humidity for 7 days. The slices are then installed in the test device. The test specimen was placed in an environment with a relative humidity of 30%-40%, and the weight loss recorded every 7d was the water diffusion. The test period was long, lasting at least 2 months.

3.2.2 German national standard

In the standard [9], the size of the specimen is stipulated as: 200mm×200mm×120mm, the bearing area is a circle with a diameter of 100mm. The operation is carried out at a concrete age of 28d to 35d. A constant water pressure of 0.5N/mm2 was applied vertically from the center of the specimen surface for three days. If the water penetrates into the bottom of the sample, the test fails and the test is terminated. If there is no sign of water seepage, immediately after the pressure is over, remove the specimen and split it from the center so that the exposed side faces down. When the splitting surface shows signs of drying (after about 5 to 10 minutes), the maximum depth of penetration along the thickness of the slab is measured, in millimeters, and the degree of water penetration is determined. The average of the maximum penetration depth obtained from the three samples shall be taken as the test result.

3.2.3 British national standard

In the standard [10], it is stipulated that the specimen can be cube, cylinder or prismatic, with a wide cross-section or diameter of no less than 150mm, and the stressed area is a circle with a diameter of 75mm. The specified pressure during the test is 500±50kPa and the holding time is 72±2h. After the specified time is reached, the specimen is split into two along the surface perpendicular to the applied water pressure. Once the crack surface is dry enough to clearly see the water penetration front, the specimen is marked and the maximum penetration depth under the measurement test area is recorded, that is, the penetration depth at the water edge is measured, so as to assess the permeability resistance of concrete.

3.3 Comparison of Chinese National Standards with European and American National Standards

Through the introduction of the above domestic and foreign water permeability test methods, there is a big difference between the European and American national standards and the Chinese national standards: for the size of the

specimen, the Chinese national and industry standards, more than 175mm×185mm×150mm round table specimen. In European standards such as the United Kingdom and Germany, cube, cylinder or prism specimens with side length or diameter not less than 150mm are used; In addition, the Chinese national standard adopts 28d standard maintenance for the maintenance of specimens, while the British, German and other European standards adopt 28d water storage maintenance. The pressure water action area in the impermeability instrument used in China's concrete impermeability test is the bottom of the whole specimen, while the pressure water action area in European standards such as the United Kingdom and Germany is about half of the edge length or surface diameter of the specimen, and the initial water pressure (about 0.5MPa) is smaller than that in China and the constant pressure time is longer (72h). European standards such as the United Kingdom and Germany use the height of seepage as an evaluation index, but the test value used is the maximum height of seepage in the specimen, while the average height of seepage is used in the Chinese standard system.

4. CHINA WATER PERMEABILITY TEST MOLD SEALING METHOD

The permeability test of concrete is the key test to detect the durability of concrete. Most of the water permeability test equipment in China is HP-4.0 concrete permeameter. The sealing between the inner wall of the stainless-steel mold and the concrete test block is the most critical problem when the concrete permeameter is used in the impermeability test. When selecting the sealing method of impermeability test, it is necessary to consider the performance of the specimen, test requirements, test conditions and other factors [11,12]. At the same time, the selection of sealing methods should meet the requirements of the test standards, and ensure that the penetration of water can be effectively prevented to ensure the accuracy and reliability of the test [13]. Therefore, it is of great significance to adopt proper sealing method and improve the success rate of sealing for improving concrete impermeability test [14].

4.1 Paraffin Rosin Sealing Method

Paraffin rosin sealing method [15] is to add a small amount of rosin to the paraffin, heat the two through the oven to melt and mix, the temperature should be controlled at about 70℃, if the heating process temperature is too high, the paraffin is easy to sublimate atomization; When the paraffin rosin mixture is slowly melted and stirred evenly, the side of the anti-permeability test block is rolled in the melted mixture, and a certain thickness of wax film is formed on the side of the anti-permeability test block after the mixture temperature drops. Finally, the test block is loaded into the test mold with the stripper and other tools, so that the test piece is flush with the bottom of the test mold, and the pressure is relieved after the test mold becomes cold, and the wax encapsulation mold is completed.

4.2 Butter Cement Sealing Method

The butter cement sealing method is to evenly mix the butter and cement according to a certain mass ratio (usually cement: butter =3.3 ~ 3.5:1) [16], apply the material evenly on the side of the concrete impermeable test block with a triangle knife, and then load it into the test mold, so that the specimen is flush with the bottom of the test mold, and scrape the excess cement butter mixture on the edge with a scraper.

4.3 Rubber Ring Sealing Method

Rubber ring sealing method adopts a rubber ring of a certain thickness instead of paraffin, divides the standard impervious test block into 3 sections along the height direction of the impervious test specimen, sets the rubber ring, and then presses the test specimen into the steel mold. Due to the elastic effect of the rubber ring, the test specimen is pressed into the test mold for a while, and then lifts the press to remove the specimen installed with the mold after the pressure is restored to stability.

4.4 Waterproof Coating Method

The waterproof coating method [17] uses polyurethane or JS composite waterproof coating to remove the specimen from the standard curing room 1 day in advance and transfer it to the impermeable operation room. Remove the cement paste film on the surface of the specimen with a wire brush. Apply the coating evenly on the side of the specimen with a brush, and form a colloidal film after about 30min; Paint the second time, after the surface is dry, paint the third time, the total thickness of the paint is about 1 ~ 2mm, and the test piece is pressed into the test mold with the press after the coating is finished, so that the bottom of the test piece is kept flush with

the bottom of the test mold, and the pressure is relieved after the press holds the pressure for 2 minutes, and the test piece with the mold is installed on the impermeability meter for test.

4.5 Plastic Winding Film Method

The plastic wrap film method [18] is to wrap the plastic wrap film with a certain thickness repeatedly on the side of the impermeable test block, and the wrap layer thickness is 0.6mm. Before entering the mold, a rubber sealing ring is set at the top of the specimen about 1cm and in the middle of the specimen. In the process of specimen entering the mold, it should be noted that the rubber sealing ring must be evenly submerged into the test mold with the specimen. To achieve a state similar to the paraffin rosin sealing method.

5. CONCLUSION

Most of the test methods prescribed in the existing standards of concrete water permeability resistance commonly used in China, Europe and the United States are simulated accelerated tests aimed at the actual situation, and the test process will not fully conform to the actual situation, so each method has limitations and applicability. For the Chinese standard, there is no mandatory provision in the specification of impermeable sealing materials and methods that must be used.

It is difficult to develop a method to meet all the actual conditions for the water permeability test method of concrete and the standard of mold sealing method. In actual operation, mature test methods can be included respectively, and the scope of use of each test method can be detailed, so that users can choose different test methods and sealing methods according to their own conditions.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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