Effect Of On Graphene Oxide the Concrete Resistance to Chloride Ion Permeability

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Abstract. The electrical resistivity test, compressive strength test and RCM test of graphene oxide were conducted to analyse graphene oxide concrete resistivity, cube compressive strength and chloride ion diffusion coefficient changing with the testing age. Then, the quantitative correlation between chloride ion diffusion coefficient and electrical resistivity, cube compressive strength was established. The results show that the compressive strength, electrical resistivity was improved while the chloride ion diffusion coefficient was reduced with the incorporation of graphene oxide. The chloride ion diffusion coefficient decrease with the increase of electrical resistivity, which the two have good inverse function correlation. Then, the chloride ion diffusion coefficient decrease with the increase of the compressive strength. At the same time, they have a good exponential function relationship with each other.

1. Introduction

In recent years, graphene has become a research hotspot at home and abroad because of its best mechanical properties, high specific surface area and flexibility. By improving the Hummers method and ultrasonic dispersion method [1], Lu Shenghua and others [2] prepared nano-graphene oxide dispersion. The experiment showed that the incorporation of graphene oxide (GO) can change the microstructure of the crystal in cement stone and promote the formation of neat and regular nanocrystalline hydration products, which can achieve the effect of strengthening and toughening. Cao Mingli and others [3] prepared graphene dispersion suspensions. The effects of graphene content on mechanical properties and microstructure of cement paste were investigated. The main reason is that the incorporation of graphene changes the shape and size of hydrated crystal, which makes it laminated and intersected, and improves the mechanical properties of cement paste. Therefore, the effect of graphene oxide on concrete is enhanced and toughened. In this paper, the resistivity, compressive strength and chloride diffusion coefficient of graphene oxide concrete were measured by experiments, and the time varying curves of resistivity, compressive strength and chloride diffusivity with the age of different ages and different ages were studied and analyzed, and graphite oxide was established. The quantitative relation between the resistivity of the concrete, the compressive strength and the diffusion coefficient of the chloride ion has laid a certain experimental foundation for the practical application of the graphene oxide concrete.
2. Text

2.1. Raw materials
The chemical composition of PO42.5R Ordinary Portland Cement manufactured by Small Field Cement; Fine aggregate is the sand and sand produced in the West Village of Chai Xi village. The fineness modulus is 2.3; Coarse aggregate is 5-20mm continuous graded crushed stone; The additive is SPC-100 superplasticizer produced by Liaoyang Cologne Company, brown yellow liquid, the water reducing rate is 35%, the solid content is 40%; The water is Shenyang tap water, in line with the national standard; Graphene oxide is produced by Newmetel New Materials Co., Ltd. improve the Hummers method and use the continuous oxidation method to prepare it. After ultrasonic treatment, the high purity and large size graphene oxide aqueous dispersions with high purity and large lamellar size can be obtained by ultrasonic treatment, the mesh number is 80, the concentration is 5 mg / ml.

2.2. Specimen preparation
In the manufacture of concrete specimens, three kinds of graphene oxide were considered to fabricate 100mm × 100mm cylinders and 100mm × 100mm cubic specimens, respectively. According to the present national standard "Test Code for cement and cement concrete in Highway Engineering" (JTG E30-2005), count the concrete specimens with a content of 0, 0.01%, 0.03%, 0.05% as GO0, GO1, GO3, GO5 respectively, and carry out 4 groups of tests with 6 specimens per group, the mix ratio of which is shown in Table 1. The specimen was statically demoulded for 24 hours and maintained in a standard curing box until the test age. The chloride diffusion and compressive strength tests were carried out.

| Number | Cement | Water | Sand | Stone | GO  | Water reducer |
|--------|--------|-------|------|-------|-----|---------------|
| GO0    | 420    | 168   | 782  | 1080  | 0   | 2.1           |
| GO1    | 420    | 168   | 782  | 1080  | 0.042 | 2.1          |
| GO3    | 420    | 168   | 782  | 1080  | 0.126 | 2.1          |
| GO5    | 420    | 168   | 782  | 1080  | 0.210 | 2.1          |

2.3. Test method and process
(1) The resistivity of concrete is measured by using a 4-electrode resistivity tester based on Wenner Method [4], the model is DZL-4000.
(2) The chloride ion diffusion coefficient of concrete is measured by HMK-10 type concrete multifunctional chloride ion durability tester.
(3) Test method for compressive strength of concrete with reference to Standard for test methods for mechanical properties of ordinary concrete (GB / T 50081-2002) [5].

3. Test results analysis and discussion

3.1. Time varying rule of resistivity
The time-varying regularity of concrete resistivity with test age, as shown in figure 1, figure 1 shows that the resistivity of concrete increases with the increase of test age. Because concrete is a three-phase composite composed of liquid, gas and solid phases, the graphic phase can be regarded as a non-conductive phase, and the existence of the liquid phase provides a free moving ion and a conducting phase. With the increase of age and the continuous hydration reaction, the internal water is consumed, the hydration products gradually fill the liquid space, the porosity becomes smaller and smaller, resulting in the liquid phase conductive space is gradually compressed, and the conductivity decreases. That is, the resistivity curve increases with age. When different amount of graphene oxide is added, the resistivity of concrete is mentioned in different degree, with the incorporation of go, the
The microstructure of concrete is improved, the inner structure is more dense, and the aperture is smaller. Before the age of 30 days, the resistivity of concrete in each group had little difference. When the age reached 56 days, the effect of graphene oxide on the resistivity of concrete appeared gradually. Go dosage is 0.03 and the effect is the best. The maximum resistivity of the specimen is $47.2 \, \text{kΩ} \cdot \text{cm}$ in 56 days, and the increase is 11%.

![Figure 1. The resistivity of time-varying curve](image1)

![Figure 2. Chloride ion diffusion coefficient of time-varying rule](image2)

3.2. Chloride ion diffusion coefficient of time-varying rule

The variation curve of chloride diffusion coefficient with age is shown in Figure 2. From figure 2, it can be seen that the chloride diffusion coefficient of concrete decreases with the increase of test age. Because concrete is a kind of water hard material, its hydration process takes a certain amount of time to complete. The compactness of concrete has great influence on the diffusion of chloride ion, and the water is not sufficient at the beginning of the test, the internal porosity of concrete is large and the chloride ion diffusion is relatively easy. As the hydration reaction continues, the internal porosity of concrete decreases and the interior becomes more and more dense. The increase of resistance to erosion and the insoluble salt of surface precipitation will lead to the gradual decay of diffusion coefficient with time, so it is considered that the diffusion coefficient of chloride ion is time-varying. The chloride diffusion coefficient of graphene oxide concrete is smaller than that of ordinary concrete. According to the test results of chloride ion diffusion coefficient of concrete for 28 days, it can be seen GO5 and GO3 can improve the impermeability of concrete and effectively hinder the penetration of chloride ions into the concrete. However, the chloride diffusion coefficient of GO1 is higher than that of ordinary concrete, which indicates that graphite oxide has a weaker ability to resist chloride ion erosion when the content of graphite oxide is small.

3.3. Concrete compressive strength with age

The time-varying curve of concrete compressive strength with test age is shown in Figure 3. It can be seen from figure 3 that the compressive strength of four groups of concrete increases with the increase of age. The degree of compactness in concrete is directly related to compressive strength. With the continuous hydration reaction in concrete, hydration products are produced continuously, the internal pore structure and interface structure of cement stone are gradually improved, the strength of concrete increases with age. The compressive strength of oxidized graphene concrete is generally higher than that of GO at the beginning of the test. As the age increases, the compressive strength of GO1 concrete is lower than that of GO0, while GO3 has the most significant effect on the compressive strength of concrete. In 56 days, when the amount of graphene oxide was 0.03% and 0.05% of the cement quality, the compressive strength of the graphene oxide increased by 13% and 10%. Respectively compared with that without adding graphene oxide cement.
3.4. Resistivity and chloride ion diffusion coefficient of correlation

For the porous material of concrete, the Nernst-Einstein equation [6, 7] can be used to reflect the relationship between the resistivity of the material and the diffusion coefficient of chloride ion. The resistivity and chloride diffusion coefficient of different amount of graphene oxide concrete at 7d, 14d, 28d, 56d were considered synthetically, the relationship between concrete resistivity and chloride diffusion coefficient with age is shown in figure 4. From figure 4, it can be seen that the chloride diffusion coefficient of GO concrete decreases with the increase of resistivity, and the two have a good inverse function relationship, which accords with the Nernst-Einstein equation.

Compared with the chloride ion diffusion coefficient, the resistivity detection of the concrete is relatively easy, and the portable concrete resistivity tester can be adopted. In the process of construction, the relation curve between chloride diffusion coefficient and resistivity of concrete is calibrated in advance, and the chloride ion diffusion coefficient of GO concrete is indirectly projected by measuring the resistivity of concrete periodically. The corrosion resistance of GO concrete was further determined.

3.5. Compressive strength and chloride ion diffusion coefficient of correlation

The relationship curve between compressive strength and chloride diffusion coefficient of GO concrete is shown in figure 5. From figure 5, it can be seen that the compressive strength of concrete at different test ages decreases with the increase of chloride diffusion coefficient, and the relationship between them satisfies the exponential function. The correlation coefficient is R²=0.97164. The test of concrete compressive strength is easier to operate than chloride diffusion coefficient. Therefore, in actual engineering, the correlation curve between concrete compressive strength and chloride diffusion...
coefficient is established in advance by test, and the compressive strength of concrete is measured by testing. The chloride diffusion coefficient of structural concrete in different test ages is obtained indirectly, and the impermeability of concrete in different period is grasped in time, which lays a foundation for the safety evaluation of structure [8].

4. Conclusion
After adding different amount of graphene oxide, the compressive strength of concrete is increased to varying degrees, while GO3 has the most significant effect on the compressive strength of concrete. The resistivity of concrete increases with the increase of test age, and the diffusion coefficient of chloride ion decreases gradually with the increase of test age. When the content of graphite oxide is low, the resistance to chloride ion erosion is weaker than that of ordinary concrete, and the effect is the best when the content of graphite oxide is 0.03 of cement mass.

The diffusion coefficient of chloride ion decreases with the increase of resistivity, which shows a good inverse function relationship and accords with the Nernst-Einstein equation. However, the diffusion coefficient of chloride ion decreases with the increase of compressive strength, and the exponential function relation between them is satisfied.

In practical engineering application, the concrete resistivity or compressive strength can be directly measured to indirectly react with chloride ion diffusion coefficient through the correlation between them, which provides a reference for the safety evaluation of concrete structures.

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References
[1] DU X, SKACHKO I, BAKER A, et al. Approaching ballistic transport in suspended graphene- [J]. Nature Nanotechnology, 2008, 3 (8): 491-495
[2] Lv Shenghua Ma Yujian, Graphene oxide on the microstructure and properties of cement [J]. concrete, 2015, 8: 51-54
[3] Mingli cao, huixia zhang, Zhang Cong. Graphene on flowability of neat cement mechanical properties and microstructure [J]. Journal of Harbin institute of technology university, 2015, 47 (12): 26-30
[5] Zhao Zhuo, Zhao Jun. Engineering structure durability [M]. Beijing: China electric power press, 2012
[6] Zhao Zhuo Ceng Li, dongwei wang. Concrete resistivity and chloride ion diffusion coefficient of correlation among test [J]. Journal of zhengzhou university, 2013, 34 (6): 76-79
[7] Peter W A, Julio D P. Physical chemistry [M]. Oxford: Oxford University Press, 2006
[8] Yuan square, Zhao Zhuo, lingyun. Fiber concrete resistivity and chloride ion diffusion coeffio- cient correlation test [J].2015, 34 (5): 1205-1209
[9] Yuan square, Zhao Zhuo, lingyun. Fiber concrete compressive strength and chloride ion diffusion coefficient of correlation studies. [J].2015, 34 (3): 711-715