Experimental Study on Anti-permeability Performance of High-performance Basalt Fiber Reinforced Concrete

Feng Chen

Engineering school, Fujian Jiangxia University, Fuzhou, Fujian, 350108, China

cfxh@fjjxu.edu.cn

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Abstract. Electric flux method was adopted in this paper to carry out experimental study on influences of fly ash and basalt fiber contents on chloride penetration resistance performance of high-performance concrete. First, influences of fly ash content were investigated by virtue of uni doped fly ash. Then, basalt fibers in diverse contents were added based on fly ash with an optimal content to achieve the optimal value of basalt fiber. Experimental results indicated that 30% was optimal for the value of fly ash content provided that slump of concrete and total electric flux were both taken into comprehensive consideration. As for the basalt fiber content, the total electric flux kept changing when it varied from 0 kg/m^3 to 1.6kg/m^3 and the maximum total electric flux could be obtained in the case that content of it reached 1.4kg/m^3.

Introduction

Not only is concrete extensively used in the overground space, but is increasingly applied in underground spaces. As a result, higher requirement is presented for durability, etc. of it. According to the existing study results, adding fibers into the concrete is able to effectively improve rupture strength, impact toughness and fatigue performance, etc. of it so that the durability can be significantly elevated. Besides, limitations to the application of concrete in engineering, such as low tensile strength, small tensile strain and other shortcomings, are also overcome. However, regarding concrete works including underground structures enriched with underground water and marine structures built in coastal regions, etc., chloridion are able to exert a dramatic influence on durability of concrete. Considering this, how to effectively improve chloride penetration resistance performance of it has become an important issue that attracts extensive attentions from the world. In this paper, basalt fibers and fly ashes of diverse contents are added into the concrete to perform experimental study on the chloride penetration resistance performance of such concrete, further explore improving actions of basalt fiber and fly ash contents on such a performance and provide guidance for practical engineering.

Experiment

Raw Material

42.5 ordinary Portland cement and short-cut basalt fiber are employed. Primary physical performance indexes are presented in Table 1. With regard to fly ash, it falls into the category of Grade II; the corresponding physical performances are given in Table 2. Fine aggregate is medium sand with a fineness modulus of 2.73. Coarse aggregate are 8-20mm granite stones with continuous grading. In the end, admixture is Polycarboxylic Water Reducer (TW-PS).

Table 1 Physical and mechanical properties of basalt fiber

Diameter/ mm	Length/mm	Comaressive strength/MPa	Elastic modulus /GPa	Ultimate elongation/%	Density/kg/m3
17	24	4150～4800	93～110	3.1	2650

Table 2 Chemical composition of fly ash

SiO_2/%	Al_2O_3/%	CaO/%	MgO/%	Fe_2O_3/%	SO_3/%
62.89	18.61	3.36	2.53	4.54	0.48

Experimental Method

Experimental study was conducted here for chloride penetration resistance of high-performance basalt fiber reinforced concrete (BFRC). Laboratory instrument consisted of a vacuum water saturation device (CABR-BSY) and an electric flux tester (CABR-RCMP6). Experimental procedures are as follows. Firstly, a 100mm×300mmΦ cylinder specimen was fabricated and then standard curing was carried out for it for 28 days (temperature at 20±2□; relative humidity at 95% and above). Afterwards, both ends of this specimen were cut off 70mm; and, the remaining section was cut into 3 cylinder test blocks with 100×50mmΦ. Subsequently, the cut specimens were dried for 4 hours at 80°C, after which side faces of them were wax-sealed followed by vacuum saturation. Finally, vacuum saturation specimens were taken out and mounted in a test flume. Besides, sealing property of these specimens was checked. In the case that the relevant sealing property was up to the requirement, 0.3mol/L NaOH solution was injected into battery anode slot while Nacl solution with a mass concentration of 3.0% was into cathode slot. Next, electric flux test was performed.

Based on the electric flux method, the total electric flux of each specimen is utilized to evaluate chloride penetration resistance performance of concrete. The related evaluation criteria are presented in Table 3. Additionally, arithmetic mean value of 3 specimens in one group serves as the measured value of such a group. Computational formula of the total electric flux is as follows.

$$Q = \int_0^T I \cdot dt \tag{1}$$

$$Q_0 = Q \times (100/95)^2 \tag{2}$$

Where, Q refers to the total electric flux that passes through the specimen (unit: C), Q_0 to the actual value of total electric flux, I to the current (unit: A) that passes through the specimen; and, T to conduction time (unit: min). During this experiment, specimens are electrified for 6 hours. Hence, T=360.

Table 3 Evaluation of concrete Cl- permeability level based on the total electric flux values through

Total Electric Flux in 6h	Cl^- Permeability Level	Typical Concrete Type
> 4000	H	Normal Concrete with Water-binder Ratio > 0.60
2000 ~ 4000	M	Normal Concrete with Water-binder Ratio from 0.50 to 0.60
1000 ~ 2000	L	Normal Concrete with Water-binder Ratio from 0.40 to 0.50
100 ~ 1000	Very Low	Fine Mineral Powder Containing Concrete with Water-binder Ratio from 0.30 to 0.40
< 100	Negligible	Fine Mineral Powder Containing Concrete with Water-binder Ratio <0.30

Experimental Results and Analysis

Experimental Analysis on Fly Ash Content

Total electric fluxes of diverse fly ash contents are also obtained by means of tests. Fig. 1 shows impacts of fly ash content on the total electric flux. According to Fig. 1, the total electric flux of concrete exhibits a trend of increase followed by decrease during the rise of fly ash content. It signifies that anti-permeability performance is intensified and then weakened and finally enhanced. Fly ash contents that make the electric fluxes arrive at the minimum (940.297C) and the maximum (1567.797C) values are 20% and 25% separately. For concrete with fly ash contents of 20% (Group 2) and 30% (Group 4), the corresponding total electric fluxes are 940.297C and 978.387C. Apparently, the difference between total electric fluxes of concrete in two groups is not large. However, according to analysis in Part 3.1, the increase in fly ash content is accompanied with gradual rise of concrete slump. By comprehensively considering slump of concrete with diverse fly ash contents and high-performance concrete's higher requirement for slump, the optimal fly ash content in high-performance concrete with the best chloride penetration resistance performance can be determined as 30% of the total gelling agent amount.

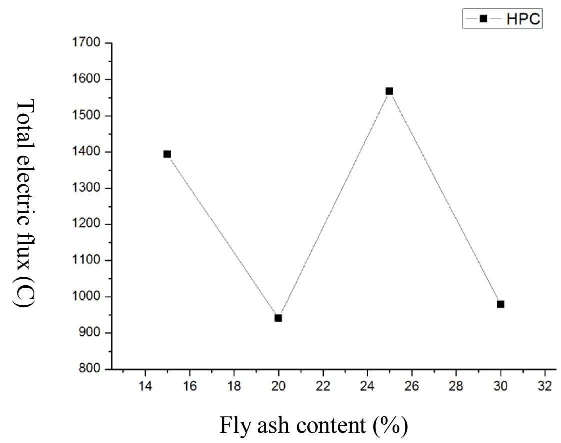

Fig.1 Influence of fly ash on the total electric flux

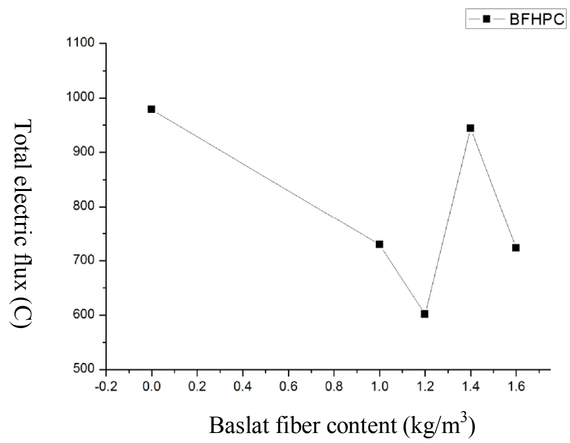

Fig.2 Influence of basalt fiber content of the total electric flux

Experimental Analysis on Basalt Fiber Content

Non-fiber high-performance concrete with a fly ash content of 30% is used as reference concrete to study impacts of basalt fiber contents on chloride penetration resistance of high-performance concrete.

Fig, 2 shows impacts of basalt fiber content on the total electric flux. Dependent on this figure, the addition of basalt fiber brings down the total electric flux of concrete electrified for 6 hours although anti-permeability performance of it is improved. When contents of basalt fiber are 1.0kg/m^3, 1.2kg/m^3, 1.4kg/m^3 or 1.6kg/m^3, the corresponding total electric fluxes respectively reduce by 25.4%, 38.4%, 33.5% or 26.1% if compared with those without basalt fiber added. Among them, the total electric flux of Group 6 concrete with a basalt fiber content of 1.2kg/m^3 decreases by 38.4% and this is the greatest reduction. The associated electric flux is only 61.5% of reference basalt (Group 4) free of basalt fiber addition. In other words, anti-permeability performance of the concrete is improved to the greatest extent. With the growth of basalt fiber content, the total electric flux of concrete firstly drops and then rises. Moreover, it arrives at the minimum value (601.939C) in the case of a content equal to 1.2kg/m^3. After that, although the total electric flux goes down slightly, the reduction amplitude fails to exceed that achieved when the corresponding content is 1.2kg/m^3. In addition, as basalt fiber content goes up, slump of concrete keeps diminishing; and, in the case that such a content reaches 1.6kg/m^3, the slump has been declined to 230mm. Considering high-performance concrete with a high requirement for slump and economic benefits of practical engineering, chloride penetration resistance performance of high-performance BFRC is favorable when content of basalt fiber is 1.2kg/m^3 that acts as the optimal value.

It is clear according to Fig. 1, 2 and Cl^- permeability level evaluation criteria of concrete presented in Tab. 3 that, among the designed 8 groups of concrete with mix proportions, Cl^- permeability levels of Groups 1 and 3 are low, while it is very low in terms of the remaining 6 groups. Therefore, high-performance concrete acquired based on 8 groups of mix proportions designed in this paper is provided with a preferable anti-permeability performance.

Conclusions

In this paper, electric flux method is employed to carry out an experimental study on anti-permeability performance of high-performance BFRC. Conclusions can be drawn as follows.

(1). Concrete slump rises together with the increase in fly ash content; but, addition of fiber is able to bring down concrete slump to a minor degree.

(2). Dependent on Cl^- permeability level evaluation criteria demonstrated in Tab. 3, the 8 groups of mix proportions designed here can be adopted to acquire high-performance concrete with a favorable anti-permeability performance.

(3). As fly ash content goes up, the total electric flux of concrete declines before increase and decrease successively. If content of it is 25%, electric flux reaches the maximum value (1567.797C).

(4). Under the circumstance that basalt fiber content is very low, addition of it brings down the total electric flux of concrete. Nevertheless, when this content rises to 1.2kg/m^3, the total electric flux arrives at the minimum value after fiber addition. If basalt fiber is added continuously, the total electric flux reduces slightly.

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