

# Study on frost resistance and abrasion resistance of fiber mesh reinforced concrete

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**Abstract:** The frost resistance and abrasion resistance of the fiber mesh reinforced concrete under the simulated treatment of external environment were studied through the frost resistance test and abrasion test. The relative dynamic modulus, the amount of spalling per unit area, the amount of abrasion per unit area and abrasion depth were used as evaluation indexes. The result shows that the frost resistance and abrasion resistance of concrete can be enhanced by fiber mesh. For the frost resistance, enhancement effect of carbon fiber mesh is better than that of basalt fiber mesh, and better than that of aramid fiber mesh. For the abrasion resistance, enhancement effect of aramid fiber mesh is better than that of basalt fiber mesh, and better than that of carbon fiber mesh. On the whole, the frost resistance and abrasion resistance of basalt fiber mesh reinforced concrete are better. Therefore, basalt fiber mesh is recommended to strengthen the frost resistance and abrasion resistance of concrete in engineering practice.

## 1 Introduction

During the use of airport pavement concrete, it is easy to be affected by the external environment such as wheel wear and freeze-thaw cycle of dry and wet. As a result, the surface layer of concrete was damaged, cracked, loosened and peeled off, which will seriously affect the service performance of airport concrete pavement, reduce the service life of airport concrete pavement, and even adversely affect the structural strength of airport concrete pavement. Therefore, it is necessary to study how to effectively enhance the ability of pavement concrete to resist the above external effects. In this regard, a large number of relevant researches have been carried out. T.sebok et al[1]. used epoxy resin as the treatment material, and believed that epoxy resin had a significant effect on the wear resistance of concrete, while the maximum particle size of aggregate had little effect on the wear resistance. Adding fiber into concrete can also enhance the frost resistance and abrasion resistance of concrete[2-5]. Gao et al. studied the principle of improving the frost resistance of concrete with cement admixture in terms of the change of concrete chemical composition and improvement of internal pore structure[6-8]. Zhu et al. indicated that polymer emulsion and surface coating with silane were helpful to improve the frost resistance and abrasion resistance of concrete, but the effect is not obvious[9, 10]. Zhao et al. explored the influence of coating on concrete durability, and the study showed that coating could effectively improve the frost resistance of concrete[11]. The above researches mainly enhance the frost resistance performance of

concrete by adding fiber, polymer, emulsion, epoxy resin and surface strengthening to concrete. The above methods can improve the frost resistance and abrasion resistance of concrete to a certain extent, but there are still many deficiencies. The enhancement effect of adding fiber and emulsion depends on whether the concrete mixture can be fully stirred, which puts forward higher requirements for the construction equipment. The effect of surface strengthening method is limited, especially in the abrasion resistance, and it is not suitable to enhance the frost resistance and abrasion resistance of the newly built concrete pavement. Considering that the concrete surface mortar layer is in direct contact with the outside world, its performance has a great influence on the abrasion resistance and frost resistance of concrete. Therefore, this paper proposes to lay fiber mesh into the concrete surface mortar layer to improve the frost resistance and abrasion resistance of concrete. The frost resistance and abrasion resistance of concrete are also affected to a certain extent by the effects of external ultraviolet radiation, chlorine corrosion and aircraft tail jet. Therefore, this paper takes ultraviolet radiation, aircraft tail jet and chlorine corrosion as environmental factors to conduct a comparative study on the frost resistance and abrasion resistance of concrete reinforced with three kinds of fiber mesh.

## 2 Experimental

### 2.1 Materials

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Cement mark is P·O 42.5R. The water was taken from the upper part of tap water standing for 24h. Sand is natural sand from Bahe River with fineness modulus of 2.8, and the test mix ratio is shown in Table 1. There are three kinds of fiber mesh, namely basalt fiber mesh, carbon fiber mesh and aramid fiber mesh. The experiments were divided into four groups, namely the control group and three fiber mesh groups. Each group consists of three specimens, including the trabecular specimen (100 mm \*100 mm \*400 mm) and the semi-cube specimen (150mm\*150mm\*75mm) for the frost resistance test and the abrasion test respectively.

## 2.2 Environmental factor simulation

### (1) Aircraft tail jet

The outer flame of the spray gun was kept 10cm away from the concrete specimen. The concrete specimen was sprayed at the end at an Angle of 40°, and kept for 6min.

### (2) Ultraviolet radiation

The JY-UV-225 UV aging machine was used to simulate ultraviolet radiation. One aging cycle is set at 12 hours, of which 10 hours are ultraviolet radiation time, and the temperature in the ambient chamber is set at 65°C. Another two hours of darkness treatment, the ambient temperature set at 45°C.

### (3) Chlorine corrosion

For the frost resistance test, the liquid in the freezing-thawing chamber was 3%NaCl solution, which was used to simulate chlorine corrosion. In order to shorten the test time, the semi-cube specimen was treated by chlorine corrosion.

## 2.3 Evaluation indexes

### (1) The frost resistance

Referring to the specification[12], the relative dynamic modulus and the amount of spalling per unit area were used as the evaluation indexes. The specific calculation method is as follows:

$$m_n = \frac{\sum_{i=1}^n \Delta m_i}{0.4 \times 0.1} = \frac{\sum_{i=1}^n \Delta m_i}{0.04} \quad (1)$$

$m_n$ : the amount of spalling per unit area (g/m<sup>2</sup>)

$\Delta m_i$ : the amount of spalling after a single freeze-thaw cycle

$$\Delta E_i = \frac{E_{di}}{E_{d0}} \quad (2)$$

$\Delta E_i$ —the relative dynamic modulus (%)

$E_{di}$ —the dynamic modulus of the specimens after freezing and thawing (MPa)

$E_{d0}$ —Initial dynamic modulus of the specimen (MPa)

### (2) The abrasion resistance

Referring to the specification[13], the amount of abrasion per unit area and the abrasion depth were used as evaluation indexes. The abrasion depth is measured by vernier caliper. The average depth at the four intersection of the two diagonals and the abrasion circle is the wear depth at the corresponding number of wear rings. The specific calculation method is as follows:

$$G_c = \frac{m_0 - m_1}{0.0125} \quad (3)$$

$G_c$ —the amount of abrasion per unit area (kg/m<sup>2</sup>)

$m_0$ —The specimen initial mass (kg)

$m_1$ —the mass of specimen after wear (kg)

0.0125—abrasion area(m<sup>2</sup>)

## 2.4 Test steps

### (1) Production of specimens

The specimens were formed in the order of mixing, pouring, vibrating, plastering, spreading fiber mesh, pulping and plastering. Here we mainly introduce the steps of spreading fiber mesh, and the rest are carried out in accordance with the specifications[12].After vibrating, the fiber mesh is placed on the plastered concrete surface, and the cement cutter is slightly pressed down to make fiber mesh contact with the concrete surface. The fiber mesh was fully in contact with the concrete surface layer by secondary vibration. Artificial pulping was carried out on the concrete surface with cement cutters to ensure that the fiber mesh was evenly spread into the concrete surface.

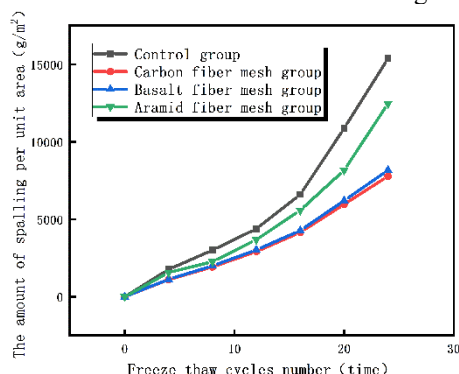
### (2) Specific test

The freezing-thawing test was carried out by single side freezing-thawing machine, and the specific operation steps were carried out according to the specifications[12]. The modulus and spalling of the specimens were measured after every 4 freeze-thaw cycles. The abrasion test was carried out by TMS-04 cement sand abrasion resistance testing machine. The specific operation was in accordance with the specifications[13]. the amount of abrasion per unit area and the abrasion depth were measured every 10 turns.

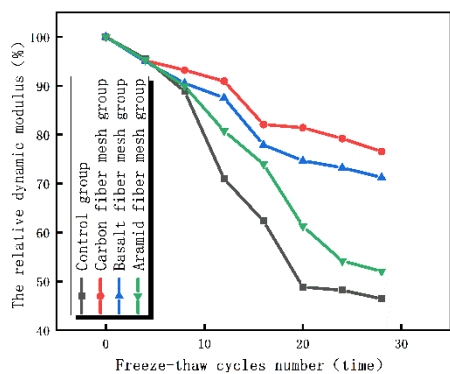
## 3 Results and discussion

### 3.1 Effect of fiber mesh on frost resistance of concrete

Freeze-thaw test was carried out according to the method in Section 2.4. The results are shown in the figure 1.



(a) the amount of spalling per unit area



(b) the relative dynamic modulus  
**Figure1** Frost resistance test results

As can be seen from Figure1 (a), with the increase of the freeze-thaw cycles number, the amount of spalling per unit area of each test group increased gradually. It indicates that with the increase of the freeze-thaw cycles number, the surface spalling of the specimen became more and more serious. At the same time, it can be seen that when the number of freeze-thaw cycles is 16-24, the curve slope of fiber mesh reinforced group is significantly lower than that of the control group, indicating that the addition of fiber mesh greatly improves the frost resistance of the specimens. Comparing the amount of spalling per unit area of each group under the same freeze-thaw cycles number, we can find that the amount of spalling per unit area shows a consistent pattern from large to small, which is control group > aramid fiber mesh group > basalt fiber mesh group > carbon fiber mesh group. It indicates that all the three kinds of fiber mesh can improve the frost resistance of concrete to a certain extent, and the enhancing effect of carbon fiber mesh is best, basalt fiber mesh is the second, and aramid fiber mesh is the last.

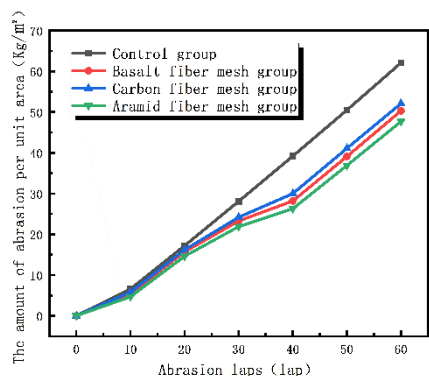
As can be seen from Figure1 (b), with the increase of the freeze-thaw cycles number, the relative dynamic modulus of the specimen decreases continuously, which shows that the structural strength of the specimen decreases gradually. At the same time, it can be seen that before the 8th freezing-thawing cycle, the enhancement effect of fiber mesh on concrete frost resistance is not obvious. But after the 8th freezing-thawing cycle, the enhancement effect of fiber mesh on concrete is effectively played. There are two reasons. On the one hand, the specimen dynamic modulus did not decrease much before the 8th freezing-thawing cycle, so the enhancement effect of fiber mesh cannot be effectively reflected. On the other hand, the spalling degree of the specimen surface is small before the 8th freezing-thawing cycle. As a result, the damage influence range failed to reach the working range of the fiber mesh. But after 8 times of freeze-thaw cycles, the surface damage of the specimen has reached a certain degree. For the control group, the destruction of the outer layer will continuously lead to the destruction of the inner layer, so the spalling amount increased sharply and the modulus decreased continuously. For the fiber mesh reinforced groups, when the damage influence range reaches the working range of the fiber mesh, the concrete surface

structure is strengthened by the pull of fiber mesh cloth and cement mortar, which slows down the inner surface of further damage. It can also be explained that due to the strengthening effect of the fiber mesh, the specimen inside the fiber mesh forms a whole with higher strength than the loose specimen outside the fiber mesh. Thus, the relative dynamic modulus of fiber mesh reinforced group decreased less. Comparing the relative dynamic modulus of each group under the same freeze-thaw cycles number, we can find that the relative dynamic modulus shows a consistent pattern from small to large, which is control group < aramid fiber mesh group < basalt fiber mesh group < carbon fiber mesh group. It indicates that all the three kinds of fiber mesh can improve the frost resistance of concrete to a certain extent, and the enhancing effect of carbon fiber mesh is best, basalt fiber mesh is the second, and aramid fiber mesh is the last.

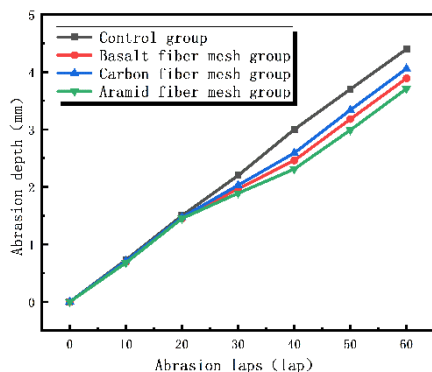
### 3.2 Effect of fiber mesh on abrasion resistance of concrete

As you can see from figure 2, compared with the control group, the amount of abrasion per unit area and abrasion depth of fiber mesh reinforced concrete have a certain degree of reduction. Under the same number of abrasion laps, the amount of abrasion per unit area and abrasion depth show the same rule, which is control group > carbon fiber mesh group > basalt fiber mesh group > aramid fiber mesh group. Take the abrasion of lap 60 as an example, compared with the control group, the amount of abrasion per unit area of basalt fiber mesh group, carbon fiber mesh group and aramid fiber mesh group decreased by 19.0%, 16.1% and 23.2% respectively, and the abrasion depth of basalt fiber mesh group, carbon fiber mesh group and aramid fiber mesh group decreased by 11.6%, 7.7% and 15.7% respectively. It can be seen from that two curve slopes of control group increase continuously as the increase of abrasion laps. But curve slopes of fiber mesh reinforced group showed a trend of first increasing, then decreasing, and then increasing. This is because when the abrasion depth reaches the working range of fiber mesh cloth, the cement mortar layer's overall resistance to the change of external action is enhanced under the action of fiber mesh cloth. Figure 3 shows the abrasion failure pattern of basalt fiber mesh reinforced concrete. It can be seen that when the abrasion laps reach 20, a small amount of fiber mesh began to be exposed, indicating that the fiber mesh begins to play a strengthening role at this time. When the number of abrasion laps reaches 40, the fiber mesh has been destroyed to a great extent, indicating that the enhancement effect of fiber mesh was greatly weakened. When the number of abrasion laps reaches 60, the fiber mesh is almost damaged, indicating that the abrasion resistance of the fiber mesh group is approximately the same as that of the control group. It can be seen from the analysis that the fiber mesh mainly plays a role when the number of abrasion laps is 20-40. In conclusion, it can be found that laying fiber mesh into the concrete surface mortar layer can improve its abrasion resistance to a certain extent. The enhancement effect of aramid fiber

mesh is best, followed by basalt fiber mesh, and carbon fiber mesh is last.

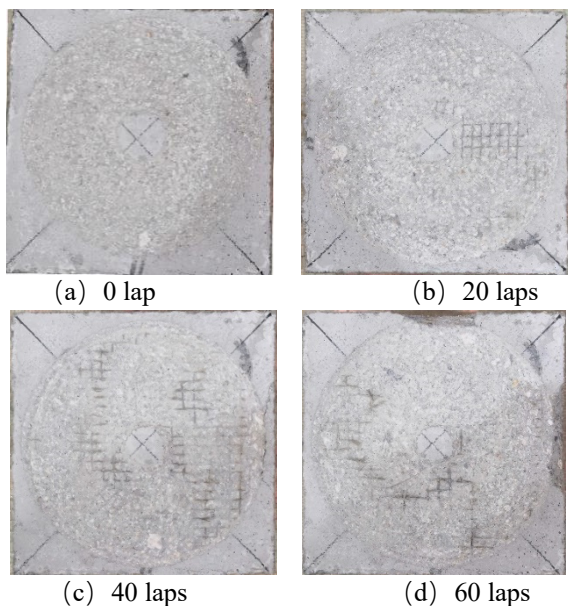


(a) the amount of abrasion per unit area



(b) the abrasion depth

**Figure2** Abrasion test results



(a) 0 lap

(b) 20 laps

(c) 40 laps

(d) 60 laps

**Figure3** Abrasion failure pattern of basalt fiber mesh reinforced concrete

## 4 Conclusion

The frost resistance and abrasion resistance of the fiber mesh reinforced concrete under the simulated treatment of external environment were studied through the frost resistance test and abrasion test. The result shows that the frost resistance and abrasion resistance of concrete can be enhanced by fiber mesh. For the frost resistance,

enhancement effect of carbon fiber mesh is better than that of basalt fiber mesh, and better than that of aramid fiber mesh. For the abrasion resistance, enhancement effect of aramid fiber mesh is better than that of basalt fiber mesh, and better than that of aramid carbon fiber mesh. On the whole, the frost resistance and abrasion resistance of basalt fiber mesh reinforced concrete are better. Therefore, basalt fiber mesh is recommended to strengthen the frost resistance and abrasion resistance of concrete in engineering practice.

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## References

1. T. Seb?K, O. Stráněl, Wear resistance of polymer-impregnated mortars and concrete, *Cement & Concrete Research* 34(10) (2004) 1853-1858.
2. P.W. Chen, X. Fu, D.D.L. Chung, Improving the bonding between old and new concrete by adding carbon fibers to the new concrete, *Cement & Concrete Research* 25(3) (1995) 491-496.
3. R. He, D. Li, S. Wang, H.X. Chen, Frost Resistance of PE/HPP Hybrid Fiber-Reinforced Concrete, *Huanan Ligong Daxue Xuebao/Journal of South China University of Technology (Natural ence)* 45(4) (2017) 87-94.
4. W. Fei, W. Boxin, Z. Zhongqiong, Influence of modified polypropylene fiber on frost resistance of hybrid fiber reinforced concrete, *Concrete* (2017).
5. J.W. Shi, H. Zhu, G. Wu, Z.S. Wu, Tensile behavior of FRP and hybrid FRP sheets in freeze-thaw cycling environments, *Composites Part B Engineering* 60(1) (2014) 239-247.
6. P.W. Gao, S.X. Wu, P.H. Lin, The characteristics of air void and frost resistance of RCC with fly ash and expansive agent, *Construction & Building Materials* 20(8) (2006) 586-590.
7. J. Jasiczak, K. Zielinski, Effect of protein additive on properties of mortar, *Cement & Concrete Composites* 28(5) (2006) 451-457.
8. E.K.K. Nambiar, K. Ramamurthy, Air-void characterisation of foam concrete, *Cement & Concrete Research* 37(2) (2007) 221-230.
9. S. Lihai, L. Yan, J. Xungao, Y. Yong, G. Wenxian, Research on frost resistance of airport pavement concrete enhanced by surface material, *Concrete* (03) (2019) 30-34+39.
10. Z. Maojiang, W. Xingzhong, G. Rui, J. Le, L. Wangchun, L. Mengshen, Study on Performance of Reinforced Concrete Material for Airport Pavement,

Journal of Shandong Agricultural University  
( Natural Science Edition ) 49(2) (2018) 295-302.

11. Z. Tiejun, Permeable coating surface treatment and concrete durability, Science Press Beijing, 2009.
12. M.o.H.a.U.-R.D.o.P.s.R.o. China, Standard for test methos of long-time performance and durability of ordinary concrete, China Architecture & Building Press Beijing, 2010.
13. T.M.o.C.o.t.P.s.R.o. China, Test Methods of Cement and Concrete for Highway Engineering, China Communications Press, Beijing, 2005.