Reduction of water absorption of concrete by surface treatment with ethyl silicate

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Abstract: Surface treatment is an effective strategy to reduce concrete water absorption and improve concrete durability in practical engineering application. In this paper, ethyl silicate and anhydrous alcohol mixed solution is chosen as surface treatment for concrete, and water absorption is tested, the test results show that ethyl silicate can effectively reduce the concrete water absorption and water absorption rate. Water absorption rate reduction rate is $82.4\%$ for T5 and $84.6\%$ for T7, the initial rate of water absorption is reduced $94.9\%$ for T5 and $94.7\%$ for T7, and the secondary rate of water absorption is reduced $73.2\%$ for T5 and $80.1\%$ for T7.

1. Introduction
Surface treatment of pavement in airport is a kind of important preventive maintenance strategy, based on the concrete surface is sprayed chemical products. The surface treatment is divided into three types: coating, impregnation and hydrophobic impregnation[1]. They can improve the compactness of the concrete surface, reduce moisture and harmful ion penetration, is important to improve the durability of concrete and character of service. At present, extensive studies have been conducted on concrete surface treatment both at home and abroad[2, 3]. Pan researched the influence of different inorganic surface treatment on the strength of cement mortar and explore the concrete carbonation performance, the test results showed that sodium fluorosilicate, Magnesium fluorosilicate and sodium silicate cannot effectively enhance the compressive strength of concrete because of as shallow infiltration, but they can improve the surface hardness of concrete, especially fluoride magnesium silicate, at the same time they also can reduce the carbonation depth of concrete,especially sodium silicate[4]. Moon has explored the improve of the Calcium-silicate compound inorganic coating on concrete, the results showed that calcium silicate inorganic coating can reduce the chloride ion permeability of concrete, enhance its frost resistance and carbonation resistance performance, this is because it can not only fill the concrete surface porosity, but also form a layer of dense film on the concrete surface[5]. Zhang et al. have demonstrated that both silane gel and silane cream can reduce concrete water absorption, in which surface treatment can reduce concrete carbonation depth, while integral water repellent concrete increased concrete carbonation depth[6]. As a repair material for cultural relic restoration, ethyl silicate can react with calcium hydroxide to enhance the compactness of concrete[7]. Franzoni has studied the application of ethyl silicate in fired-clay bricks. The research showed that ethyl silicate can reduce the water absorption rate of fired-clay bricks, enhance their compressive strength, and penetrate the brick to a depth of up to 10 mm[8]. This paper intends to explore the influence of ethyl silicate surface treatment on water absorption.
absorption of concrete.

2. Materials and methods

2.1 materials

Concrete materials have a great influence on concrete performance. In this test, PO 42.5 ordinary Portland cement is used for cement, river sand with fineness modulus of 2.75 is used, coarse aggregate is 5-10, 10-20, 20-40 three levels, and it is mixed in accordance with the ratio of 1:2:3 and FDN water-reducing agent is used. See Table 1 for the concrete mix ratio.

| mix (kg/m³) | Vb/s | 28 d flexural strength |
|-------------|------|------------------------|
| Cement      | water | sand | Coarse aggregate | FDN | 28 d flexural strength |
| 330         | 125.4 | 612.1 | 1434.0 | 0.4% | 28 | 6.7 |

In this experiment, two ethyl silicate mixed solutions were used. The ratio of which was 55 wt.% ethyl silicate and 45 wt.% anhydrous ethanol were mixed is labeled as T5, and the ratio of which was 75 wt.% ethyl silicate and 25 wt.% anhydrous ethanol was labeled as T7. Ethyl silicate used is TEO-40, which means silica content (SiO₂) content is 40-42%.

2.2 Test methods

The methods refers to ASTM C1585-13[9], 150×150 ×150mm concrete samples were cured for 28 days in a standard curing chamber (T=20±1℃, RH≥95%). They were cut along the middle line of the specimen and used as test samples, and the cutting surface was used as the water absorption surface. Firstly, the samples were dried in the oven at T=60±5℃ until constant weight, and then they are taken out for surface brushing treatment. Since the anhydrous ethanol volatilized quickly, the samples were brushed 4 times a day at an interval of 10min and continuously for 3 days. After finishing the brush, continue curing for 15 days in the indoor environment, and then coat the side of the samples with epoxy resin. After curing the epoxy resin, put it into the device as shown in the Figure 1 for the sample. After a certain interval, the concrete is taken out to measure its quality, accurate to 0.1g. Three samples were tested in each group, and the average value was taken as the final result.

![Figure 1. Water absorption test device](image)

3. Results & Discussion

![Figure 2. Water absorption with time](image)
The water absorption mass is converted into water absorption according to formula 1. Based on the Figure 2, the following conclusions can be drawn: (1) concrete water absorption shows a trend of first fast and then slow, this is because concrete water absorption gradually saturated; (2) After being treated with ethyl silicate, the water absorption of concrete decreased significantly, N, T5 and T7 absorption is 4.15, 0.73, 0.64 mm, respectively. The water absorption of T5 decreased by 82.7% on 7 day while of T7 decreased by 84.6%.

\[ I = \frac{m_1}{a \cdot b} \]  

(1)

In Formula 1: I-Absorbtion, mm; m_1-Water absorption mas change, g; a-The exposed area of the specimen, 150×150≈22500 mm² ; d-The density of the water, 1 g/cm³.

\[ I = S_t \sqrt{t} + b_1 \]  

(2)

\[ I = S_s \sqrt{t} + b_2 \]  

(3)

Where: I-Water Absobtion, mm;
S_t- The initial rate of water absorption, mm/√min;
S_s- The secondary rate of water absorption, mm/√min;
b_1, b_2- The fitting parameters, mm;
t-Time, min.

Table 2. Fitting results

| Type | S_t \(10^2\) mm/√min | b_1 \(10^3\) mm | R² | S_s \(10^3\) mm/√min | b_2 \(10^1\) mm | R² |
|------|----------------------|-----------------|----|----------------------|-----------------|----|
| N    | 7.559                | 0.575           | 0.99 | 25.17                | 17.28           | 0.97 |
| T5   | 0.3882               | 0.1323          | 0.98 | 6.749                | 0.508           | 0.99 |
| T7   | 0.4033               | 0.6343          | 0.95 | 5.003                | 1.206           | 0.99 |

Since the water absorption is linearly dependent on \(\sqrt{t}\), the initial rate of water absorption and secondary rate of water absorption of concrete are obtained by regression according to ASTM C1585-13 by Formula 2 and 3. The initial rate of water absorption is about 0-6 h and the secondary rate of water absorption is about 1-7d. See the table for the specific results. It can be seen that ethyl silicate can significantly reduce the initial and secondary rate of water absorption, among which the reduction of initial rate is the most obvious, reaching 94%. Comparing T5 and T7, although T7 is slightly better than T5, the difference between them is small, the initial rate reduction rate compared with N (no treatment) is 94.9% for T5 and 94.7% for T7, and the secondary rate reduction rate is 73.2% for T5 and 80.1% for T7.

4. Conclusions

From absorption tese and discussion, two conclusions can be drawn:

1. Ethyl silicate can effectively reduce the water absorption and the rate of absobtption of concrete, especially the initial rate of water abosbtion of concrete.

2. The mixed solution of 55% and 75% mass fraction ethyl silicate has similar effect, indicating that 55% ethyl silicate can meet the requirements in reducing the water absorption of concrete.

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