Evaluation of foam inducing and foam stabilizing properties of different kinds of concrete air entraining agents

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Abstract. Water solution method, saturated calcium hydroxide solution method and cement solution method were used to evaluate the foam inducing and foam stabilizing properties of seven different types of air entraining agents. The evaluation results of the three methods were compared with the initial air content of concrete, the air content in 1h and the change rate of air content in 1h. The results show that the corresponding relationship between the test results of water solution method and concrete is the best.

1. Introduction

As an important component of concrete admixture, air entraining agent plays an important role in concrete. Air entraining agent can improve the workability, frost resistance, chloride ion permeability and durability of concrete when it is introduced into concrete[1-3]. At present, the most common method to evaluate the foam inducing and foam stabilizing performance of air entraining agent is to test the initial air content and time-dependent air content of fresh concrete, However, this method is tedious, time-consuming and easily affected by the fluctuation of cement and aggregate. Many scholars have studied how to evaluate the air entrainment effect of air entraining agent simply and quickly. Guoju Ke [4], Huazhen Lai [5] and so on have made preliminary judgment on the bubble initiation and foam stability of the air entraining agent through the foam shaking test of cement slurry. However, manual bubbling method requires manual operation. The amplitude of oscillation, the vibration strength and the recording time will be greatly error due to manual factors. Guoju Ke [6] et al. Found the concentration of air entraining agent with inflection point of surface tension by testing the surface tension of saturated calcium hydroxide solution with different concentrations of air entraining agent, and qualitatively and quantitatively judged the air entraining effect of air entraining agent, but this method could not evaluate the foam stabilization performance of air entraining agent.

In order to solve the limitations of manual foam shaking method, this paper selects three test methods, namely water solution method, saturated calcium hydroxide method and cement solution method, analyzes the foam inducing and foam stabilizing performance of different types of concrete air entraining agent, and finally determines a test method of foam inducing and foam stabilizing performance that matches the concrete performance by combining with the air content and time-dependent air content test of concrete.
2. Experimental

2.1. Materials

2.1.1. Cement

The chemical performance of cement is shown in Tab 1.

| Fe2O3/% | Al2O3/% | SiO2/% | CaO/% | MgO/% | SO3/% | Cl/% | Na2O/% | f-CaO/% | Loss |
|--------|---------|--------|-------|-------|-------|------|--------|---------|------|
| 3.47   | 4.54    | 22.89  | 61.98 | 2.06  | 2.76  | 0.022| 0.53   | 0.88    | 1.23 |

2.1.2. Sand and Stone

The sand is medium sand meeting the requirements of zone II in GB / T 14684, with fineness modulus of 2.8 and mud content of 0.9%; the stone is gravel with nominal particle size of 5 mm-20 mm meeting the requirements of GB / T 14685.

2.1.3. Air entraining agent

The performance indexes of air entraining agent are shown in Tab 2.

| Code | Main components          | State | PH value | Solid content/% | Content of solid chloride ion/% |
|------|--------------------------|-------|----------|-----------------|-------------------------------|
| AE-1 | /                        | liquid| 4.82     | 44.37           | 0.002                         |
| AE-2 | rosin soaps              | liquid| 8.61     | 27.72           | 0.004                         |
| AE-3 | α-alkenylsulfonates      | liquid| 7.50     | 23.43           | 0.262                         |
| AE-4 | Coconut oil based glucoside| liquid| 8.09     | 29.32           | 0.310                         |
| AE-5 | Coconut diethanolamide   | liquid| 6.85     | 44.89           | 0.008                         |
| AE-6 | Fatty alcohol polyoxyethylene ether sulfate | liquid| 6.13     | 38.52           | 0.327                         |
| AE-7 | Sodium alkyl sulfate     | liquid| 6.15     | 40.17           | 0.018                         |

2.1.4. Ca(OH)2

Analytical purity.

2.2. Test methods

2.2.1. Aqueous solution method

300 g of air entrainer solution with 0.5% of solid content is configured in 1000 ml customized measuring cup. The dosage of air entrainer is accurate to 0.01 g, the amount of deionized water is accurate to 0.1 g, and the solution is evenly dispersed by gently stirring the solution with glass rod.

Set the speed of the electric stirrer to (1000 ± 10) r/min, accurate to 10 r/min. Place the stirring rod of the electric stirrer in the middle of the measuring cup, adjust the position of the measuring cup vertically until the blade of the polytetrafluoroethylene stirrer is in the middle and lower part of the air entraining agent solution, turn on the switch of the electric stirrer, use a stopwatch to count the time, stir for (60 ± 1) s, and immediately turn off the switch of the electric stirrer to stop mixing. Then take out the measuring cup and immediately record the initial bubble height $V_0$ value in the measuring cup within 25 S-35 s (counting from the end of mixing). After standing for 1 h (counting from the end of mixing), record the bubble height $V_{th}$ value again.

2.2.2. Cement solution method.

Prepare air entraining agent solution according to the water solution method; weigh 5 g of reference cement to the accuracy of 0.1 g.
Set the speed of the electric stirrer to (1000 ± 10) r/min, accurate to 10 r/min. Add the reference cement into the measuring cup, and then place the stirring rod of the electric mixer in the middle of the measuring cup. The other steps are the same as the water solution method.

2.2.3. Saturated calcium hydroxide solution method
The saturated sodium hydroxide solution is used to prepare 300 g of air entraining agent solution with 0.9% of the solid content. The rest steps are the same as that of the water solution method.

2.2.4. Evaluation of foam stability
The foam stability of water solution method, cement solution method and saturated calcium hydroxide solution method is expressed by 1 h bubble time loss ratio $\Delta \varphi_{1h}$. The smaller the $\Delta \varphi_{1h}$ is, the better the foam stability is. The $\Delta \varphi_{1h}$ is calculated according to formula (1).

$$
\Delta \varphi_{1h} = \frac{V_0 - V_{1h}}{V_0} \times 100\%
$$

Where $\Delta \varphi_{1h}$ is 1h bubble time loss ratio (%), $V_0$ is initial bubble height (mL), $V_{1h}$ is 1h bubble height (mL).

Take the arithmetic mean value of the two determination results as the determination result.

2.2.5. Concrete performance test
The concrete mix proportion shall meet the requirements of GB 8076. The air content of concrete and the 1h air content shall be determined according to the method specified in GB 8076. The change rate of 1h air content shall be calculated according to formula (2).

$$
\Delta \vartheta_{1h} = \frac{Q_0 - Q_{1h}}{Q_0} \times 100\%
$$

Where $\Delta \vartheta_{1h}$ is change rate of 1h air content (%), $Q_0$ is initial air content (%), $Q_{1h}$ is 1h air content (%).

3. Results and discussion

3.1. Concrete performance test
The initial air content, 1h air content and change rate of 1h air content of seven different types of air entraining agents under the condition of equal volume of solid admixture are investigated. The test results are shown in Fig.1.

![Figure 1](image)

Figure 1 The initial air content, 1h air content and change rate of 1h air content of air entraining agents

As shown in Figure 1, the initial air content of air entraining agent from large to small is AE-1 > AE-7 > AE-6 > AE-5 > AE-4 > AE-3 > AE-2 under the condition of equal fold solid content, and the air
content is the same trend at 1 h. The change rate of air content at 1 h from large to small is \( AE-5 > AE-6 > AE-1 > AE-7 > AE-4 > AE-2 > AE-3 \), and all are less than 16%. The smaller the change rate of air content at 1 h, the foam stabilizing properties of air entraining agent is the better. Therefore, combined with the initial air content and 1 h time air content of air entraining agent, it can be found that the comprehensive properties of AE-1 and AE-7 are better, while the comprehensive properties of AE-2 and AE-3 are worse.

3.2. Evaluation of air entraining agent by aqueous solution method

The foam inducing and foam stabilizing properties of seven different types of air entraining agents were investigated by aqueous solution method. The results are shown in Fig. 2.

![Figure 2 Evaluation of air entraining agent by aqueous solution method](image)

As shown in Figure 2, the initial bubble height of air entraining agent from large to small is \( AE-5 > AE-7 > AE-1 > AE-4 > AE-2 > AE-3 > AE-6 \), and the bubble height at 1 h is the same trend; the 1 h bubble time loss ratio from large to small is \( AE-5 > AE-1 > AE-6 > AE-7 > AE-2 > AE-4 > AE-3 \), and they are all less than 16%. It can be found that the comprehensive properties of AE-1, AE-5 and AE-7 are better than those of AE-2, AE-3 and AE-6. There is a certain corresponding relationship between the results and the test results of concrete properties.

3.3. Evaluation of air entraining agent by saturated calcium hydroxide solution method

The foam inducing and foam stabilizing properties of seven different types of air entraining agents were investigated by saturated calcium hydroxide solution method. The results are shown in Fig. 3

![Figure 3 Evaluation of air entraining agent by saturated calcium hydroxide solution method](image)
As shown in Fig. 3, the initial bubble height of air entraining agent tested by saturated calcium hydroxide solution method is relatively low, and the initial bubble height of air entraining agent from large to small is AE-1 > AE-7 > AE-5 > AE-6 > AE-2 > AE-3 > AE-4. Except AE-6. The 1h bubble time loss ratio is more than 14%, which indicates that the foam stability of the air entraining agent tested by this method is poor. Compared with the water solution method, the corresponding relationship between the test results of saturated calcium hydroxide solution method and the test results of concrete performance is poor. The reason may be that this test method adopts the equal bending solid method to test, and the saturated calcium hydroxide solution can not completely imitate the air entraining agent in the concrete system environment. Therefore, this method can not achieve a good corresponding relationship with concrete.

3.4. Evaluation of air entraining agent by cement solution method

The foam inducing and foam stabilizing properties of seven different types of air entraining agents were investigated by cement solution method. The results are shown in Fig. 4.

As shown in Fig. 4, the initial bubble height of the cement solution method is higher than that of the aqueous solution method and the saturated calcium hydroxide solution method. This may be because the fine cement particles in the cement solution can be used as the "core" to help the foaming of the air entraining agent. The initial bubble height of the air entraining agent from large to small is AE-7 > AE-3 > AE-1 > AE-5 > AE-4 > AE-6 > AE-2. The 1h bubble time loss ratio is more than 19%, and four samples of air entraining agent are more than 40%, which indicates that the foam stability of air entraining agent tested by cement solution method is worse than that of the other two methods. This may be because the cement particles will be brought into the air bubbles, which not only improves the foam ability, but also introduces unstable factors, which makes the air bubbles easier to break. To sum up, the test results of cement solution method have the worst corresponding relationship with the test results of concrete compared with the other two methods.

![Figure 4: Evaluation of air entraining agent by cement solution method](image_url)

### 4. Conclusion

(1) The cement solution method, saturated calcium hydroxide solution method and cement solution method overcome the artificial unstable factors introduced by manual shaking bubble method, and the accuracy of the method is higher.

(2) Seven different types of air entraining agents were evaluated by cement solution method, saturated calcium hydroxide solution method, cement solution method and concrete method. The results show that the comprehensive properties of AE-1 and AE-7 are better than those of AE-2 and AE-3.

(3) The results show that the water solution method has the best corresponding relationship with the concrete test results.
References

[1] Yuan CK, Yan BC, wang YZ, Cheng.TQ. Experimental study on frost resistance and chloride ion permeability of air entrained concrete [j]. Waterway Port, 2020, 41 (05), 590-597.

[2] Ma LJ. The influence of three air entraining agents on the impermeability of concrete [j]. Sichuan cement, 2020 (10), 13-14.

[3] Yan ST, Zhang Q, Lu Y, Xie HD. Experimental study on the effect of air entraining agent on concrete durability [j]. Commercial concrete, 2020 (08), 39-41.

[4] Ke GJ, Tian B, Wang JL. Study on evaluation method of air entraining agent for pavement concrete [j]. Journal of building materials, 2014, 17 (04), 743-748.

[5] Li HZ. Analysis and application performance evaluation of air entraining agent [j]. Fujian building materials, 2018 (11), 13-15.

[6] Ke GJ. An evaluation method for the air entrainment effect of cement concrete air entrainment agent [j]. Concrete, 2014 (09), 124-126.