Effects of Urea-formaldehyde Resin on Physical Properties and Frost Resistance of Autocalved Aerated Concrete Prepared with Fly ash

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Abstract. In this paper, the effect of urea-formaldehyde resin on aerating process and properties of autocalved aerated concrete (AAC) prepared with fly ash are studied. The results indicate the urea-formaldehyde resin has a relatively obvious water-reducing effect and a certain defoaming effect. The compressive strength of the fly ash AAC added urea-formaldehyde resin has not been significantly improved. The maximum amount is 0.5% and 0.25% is a suitable amount. In addition, the resin can obviously improve the frost resistance of AAC because of its film-forming in aerated concrete hydration products.

1. Introduction
AAC is a lightweight uniform cellular material. As a homogeneous lightweight cellular material, AAC has been widely accepted because of its significant contribution to structure dead load reduction, fire protection, building thermal insulation, sound damping, and so on [1]. However, the high porosity of aerated concrete makes it have the characteristics of strong hygroscopicity, poor frost resistance and relatively low strength [2]. Liu Suxia et al. added sodium hexametaphosphate and sodium pyrophosphate as a dispersant and surfactant in aerated concrete to enhance the physical and mechanical properties of aerated concrete blocks [3-4]. The mechanism of the admixture on the aerated concrete can be analysed from the following three aspects: firstly, adjusting the pore structure of the autoclaved aerated concrete block to improve the stability of the cast slurry; Secondly, promoting the calcium and silicon reaction of the block under autoclaved curing conditions, accelerate the conversion of hydrates to tobermorite, thereby improving its strength; Thirdly, controlling the effect of gas generator aluminum powder, and making the bubbles uniform and stable, reducing the dry density of the products, thereby making the dry density smaller.

In this paper, a series of experiments has been done to determine the optimum amount of the resin and its effect on the gassing state, microstructure and properties of aerated concrete.

2. Experimental

2.1. Materials

2.1.1. Fly ash
The main chemical components of fly ash are shown in Table 1. The main constituents of fly ash are SiO$_2$ and Al$_2$O$_3$. They are 46.04% and 40.07% respectively and the total content is upon 85%.

| Technical index | value |
|-----------------|-------|
| CaO (%)         | 4.96  |
| MgO (%)         | 1.56  |
| SiO$_2$ (%)     | 46.04 |
| Al$_2$O$_3$ (%) | 40.07 |
| Loss (%)        | 4.88  |

2.1.2. Urea-formaldehyde resin

The urea-formaldehyde resin is a pale yellow viscous liquid. The properties of the resin are showed in Table 2.

| Technical index      | value |
|----------------------|-------|
| Solid content (%)    | 45    |
| Viscosity (25°C, cps)| 150-260|
| pH (25°C)            | 9     |

2.1.3. Other materials

The cement is ordinary silicate cement and its strength is 42.5MPa. The main calcium material is a moderate lime and its active CaO content reaches 70%. The foaming agent is aluminium powder.

2.2 Methods

The major process of experiment is divided into four stages. Firstly, the resin is evenly mixed with water and consequently fly ash, gypsum are added into the water. The mixture stirs for 3 minutes. Then add cementing materials composed of lime and cement and stirred for 1 minute. The aluminum powder is added with a small portion of water. Secondly, the slurry is put into mould and cured at 40°C in drying oven for 4-5 hours. Thirdly, the blocks are put into autoclave. Finally, the compression strength and volume weight of AAC blocks are determined.

The parameters of autoclave of this experiment adopted are as follows: temperature rises for 2h and reaches 195°C, keep on 6 h, press reaches 1.3 MPa, and then 2h temperature decreases.

3. Result and discussion

3.1. Influence of admixture amount on the water to material ratio and compressive strength of AAC

![Figure 1 Gassing state when maintaining the same fluidity](image)
The resin admixture amount is 0%, 0.25%, 0.50% and 0.75% of the mass of the raw materials, respectively. As the amount of resin admixture increases, the water to material ratio decreases. Under the premise of maintaining the same fluidity with the blank slurry, the larger the amount of the admixture is, the more viscous the slurry is, and the breadhead cannot be started normally (Figure 1). The water to material ratio should be adjusted to ensure the normal gassing state (Figure 2). From the gassing state with different resin admixture amount, it can be seen the urea-formaldehyde resin has a relatively obvious water-reducing effect and a certain defoaming effect.

Table 3 shows the dry bulk density and strength of the aerated concrete block with different amount of admixtures after autoclaving. The resin admixture does not significantly improve the compressive strength of the aerated concrete. Except for the blank comparison test block, when the amount of the admixture is 0.25%, the aerated concrete block has the highest compressive strength. When the amount of the admixture is 0.75%, the block becomes soft and has no strength.

| Amount of admixture (%) | Vwater/Vbinder | ρ (kg/m³) | Compressive strength (MPa) |
|------------------------|---------------|----------|--------------------------|
| 0                      | 0.60          | 496      | 3.9                      |
| 0.25                   | 0.56          | 527      | 4.1                      |
| 0.50                   | 0.54          | 518      | 3.6                      |
| 0.75                   | 0.52          | 601      | -                        |

3.2. Analysis of AAC hydrate products
A XRD pattern of fly ash AAC added with different content of resin is shown in Figure 3. It can be seen from XRD analysis that the hydrate products after autoclaving of AAC are mainly hydrated calcium silicate, tobermorite and calcium carbonate, of which calcium carbonate may come from impurities in the raw lime. There is no significant change in the XRD diffraction peak after the admixture is incorporated. The appearance of fly ash AAC hydrate products in SEM looks like willow-like or needle-like which is the typical shape of fly ash AAC hydrate products.
3.3. Frost resistance of AAC

A SEM image of fly ash AAC hydration products added different amount of resin is shown in Figure 4. It can be seen from the SEM that the resin has a significant effect on the microscopic appearance of AAC. Compared with the blank, the hydrate products of test samples added urea-formaldehyde resin are coated with a film formed by the resin when it is in the progress of curing.

The freeze-resistance test of 25 freeze-thaw cycles is carried out after autoclaving of the aerated concrete with an amount of 0.25%. After testing, the mass loss of the test block is 1.9%, and the strength after freezing is 3.0 MPa, which can meet the frost resistance requirements in cold regions.

4. Conclusion

The urea-formaldehyde resin has a relatively obvious water-reducing effect and a certain defoaming effect. As the amount of admixture increases, the water to material ratio is greatly reduced.

Compared with the blank sample, the compressive strength of the fly ash AAC added urea-formaldehyde resin has not been significantly improved. The admixture has a tendency to decrease in strength with its amount increasing. The maximum amount is 0.5% and 0.25% is a suitable amount.
The frost resistance of fly ash AAC used urea-formaldehyde as admixture is significantly enhanced, which can meet the frost resistance requirements in cold regions.

References

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