Basic test of mix proportion of foamed concrete with aluminum powder as foaming agent

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Abstract. In this paper, the method of producing bubbles by the reaction of aluminum powder and sodium hydroxide is used to make foam concrete test blocks and test their expansion rate and compressive strength. The foamed concrete was made through experiments of controlling the amount of cement, water and the relative content of aluminum powder, and the best mix ratio was selected from the comparative analysis of the compressive strength of 7d, 14d and 28d concrete. Experimental results: The amount of cement and the water-cement ratio and the relative content of aluminum powder have a significant impact on the compressive strength and expansion rate. Conclusion: Starting from the ratio of the relative content of aluminum powder in foamed concrete to the amount of cement, the analysis of compressive strength and expansion rate provides a theoretical basis for the future study of its mix ratio, which greatly shortens the test time and saves costs.

1. Introduction
Foamed concrete, also known as foamed concrete or lightweight concrete, is made by processing various admixture materials. When making, the materials are processed through physical or chemical methods. The treatment is mainly to introduce air bubbles into the gelled slurry, and then put it into a fixed mold. After a certain period of time of coagulation and hardening, a new type of light insulation material with a large number of closed pores is formed by natural curing, and it contains uniform pores; Because of its lightweight, good thermal insulation performance, sound insulation and fire resistance, good overall performance, low elasticity and shock absorption, strong waterproof performance, convenient production and processing, good environmental performance, convenient construction, etc., it is mostly used as slope-finding for roof insulation, ground insulation cushion, foundation pit feeling of upturn beams, and wall pouring. Now the country takes "green environmental protection" as the keynote for the development of future building materials. Yu, X.G., et al. [2] studied coal gangue foam concrete, and analyzed coal gangue by studying the ratio of water to material, the grinding time of calcined gangue and the amount of foam. To analyze the influence of dry apparent density and compressive strength of coal gangue foam concrete; Sun, W.B., et al. [3] studied ceramsite foam concrete, focusing on ceramsite content, foam content, cement content, sand ratio, water consumption, fly ash. The influence of mixing amount on the strength of ceramsite foam concrete, and the optimal mixing amount of each component has been determined. Their research has played an important role in the development of foam concrete. However, foam concrete has the characteristics of high open porosity, easy cracking, water absorption, etc., reducing its open porosity and reducing bubble loss, foam concrete will have more room for improvement in thermal insulation performance.
This paper conducts preliminary experiments on the mixing ratio of foam concrete with aluminum powder as the foaming agent. By controlling the three variables of water-cement ratio, cement quantity and aluminum powder quantity, the volume expansion rate and dry density of foam concrete under each group ratio are controlled. And the compressive strength is studied, and the optimal mix ratio is formulated based on the C5 strength foamed concrete, which provides a theoretical reference for further research on enhancing the bubble stability of the foamed concrete and increasing the thermal insulation.

2. Test materials and design

2.1. Test materials

(1) Cement: PO42.5 ordinary portland cement produced by Jilin Dequan Cement Co., Ltd;

(2) Aluminum powder: 45μm aluminum powder produced by Binzhou Xilong Building Materials Co., Ltd. The chemical composition is shown in Table 1;

(3) Tab. 1 Chemical Composition of Aluminum Powder

| Particle size (μm) | Al (Min) | Fe (Max) | Si (Max) | Cu (Max) | H2O (Max) |
|-------------------|----------|----------|----------|----------|-----------|
| 45                | 99.7     | 0.15     | 0.10     | 0.01     | 0.10      |

(4) NaOH: Granular sodium hydroxide produced by Tianjin Komiou Chemical Reagent Co., Ltd.;

(5) Water: Tap water of Yanji City;

2.2. Mix design of foam concrete

According to the general relationship between the dry density grade and the strength in the JG/T 266-2011 "Foam Concrete" specification, the foam concrete with a design strength of C5 has a dry density grade of A10-A12, which is a dry density of 1000-1200kg/m³. According to the foam concrete design idea[4]:

\[ M_c = \frac{\rho_{dry}}{S_a} = \frac{1000 \text{ kg/m}^3}{1.2} = 833.33 \text{ kg/m}^3 \]

(1) \( \rho_{dry} \): design dry density of foam concrete (kg/m³), temporarily set as 1000 according to design parameters;

(2) \( S_a \): mass coefficient determined by the total amount of dry materials and the total amount of non-evaporates in the finished product after 28 days of curing of foam concrete, ordinary silicic acid Salt cement is taken as 1.2;

(3) \( M_c \): 1m³ of the cement dosage of foamed concrete (kg);

The water-cement ratio is 0.4, 0.5 and 0.6; the cement volume is 400kg/m³, 500kg/m³, 600kg/m³, the relative cement content of aluminum powder is 0.1% and 0.2%, and the granular sodium hydroxide is equipped with 5% NaOH. As a launch accelerator. The mixing ratio numbers A41, B52, and C61 respectively represent the mixing ratio of cement quantity of 600kg/m³, the water-cement ratio of 0.4, and aluminum powder relative to cement content of 0.1%; cement quantity of 500kg/m³, the water-cement ratio of 0.5, and the mixing ratio of aluminum powder relative to cement content is 0.2%; the cement volume is 400kg/m³, the water-cement ratio is 0.6, and the aluminum powder relative to cement content is 0.1%. 18 sets of 100×100×100mm concrete test blocks were produced.

In order to study the volume expansion rate of foamed concrete in this test, first reduce the amount of cement in each square of concrete, preliminary design A41, A42, A51, A52, A61, A62, B41, B42, B51, B52, B61, B62, C41, C42, C51, C52, C61, C62 eighteen kinds of mixing ratios, see Table 2 for details, prepare samples according to the mixing ratios, and test their compressive strengths for 7d,
14d and 28d after natural curing. After the test, select the best through the data further debugging and optimization of the mix ratio[5].

| Serial number | Number of test blocks in each group | Cement(kg) | Water(kg) | Water-cement ratio | Aluminum powder (%) | Relative cement content |
|---------------|-------------------------------------|------------|-----------|-------------------|---------------------|------------------------|
| A41           | 9                                   | 900        | 200       | 0.4               | 0.2                 | 0.1                    |
| A42           | 9                                   | 800        | 200       | 0.4               | 0.2                 | 0.1                    |
| A51           | 9                                   | 600        | 200       | 0.5               | 0.2                 | 0.1                    |
| A52           | 9                                   | 600        | 200       | 0.5               | 0.2                 | 0.1                    |
| A61           | 9                                   | 500        | 200       | 0.5               | 0.2                 | 0.1                    |
| A62           | 9                                   | 500        | 200       | 0.5               | 0.2                 | 0.1                    |
| B41           | 9                                   | 200        | 200       | 0.4               | 0.2                 | 0.1                    |
| B42           | 9                                   | 200        | 200       | 0.4               | 0.2                 | 0.1                    |
| B51           | 9                                   | 240        | 200       | 0.6               | 0.2                 | 0.1                    |
| B52           | 9                                   | 240        | 200       | 0.6               | 0.2                 | 0.1                    |
| B61           | 9                                   | 200        | 200       | 0.4               | 0.2                 | 0.1                    |
| B62           | 9                                   | 200        | 200       | 0.4               | 0.2                 | 0.1                    |
| C41           | 9                                   | 240        | 200       | 0.4               | 0.2                 | 0.1                    |
| C42           | 9                                   | 240        | 200       | 0.4               | 0.2                 | 0.1                    |
| C51           | 9                                   | 300        | 200       | 0.6               | 0.2                 | 0.1                    |
| C52           | 9                                   | 300        | 200       | 0.6               | 0.2                 | 0.1                    |
| C61           | 9                                   | 360        | 200       | 0.6               | 0.2                 | 0.1                    |
| C62           | 9                                   | 360        | 200       | 0.6               | 0.2                 | 0.1                    |

3. Fabrication of Foam Concrete Specimen

According to the relevant technical regulations in JG/T 266-2011 "Foam Concrete", prepare 100 mm×100 mm×100 mm cube test blocks, 18 groups of test blocks with different mixing ratios, each group prepares 9 blocks, weighed according to the designed ratio. Measure the quality of each component, put the cement, water and NaOH solution into the mixer and mix at high speed for 240s, then put the aluminum powder into the mixer and continue to mix at high speed for 90s, put it into the mold and maintain it in the open air at room temperature, and cut off the bread head after 18 hours. At the predetermined age, 3 pieces were taken out and wiped dry for compressive strength determination [6]. Figure 1 shows the production of test blocks and finished products.

Fig.1 the Test Block and Finished Product Drawing
4. Test results and analysis

4.1. Analysis of volume expansion rate

The trend of the volume expansion rate change curve in the experiment is basically the same. Figure 2 shows that the water-cement ratio affects the expansion rate of foamed concrete. When the cement content is 400 kg/m³, the expansion rate gradually decreases with the increase of the water-cement ratio; when the cement content is 500 kg/m³, the expansion rate first decreases and then increases with the increase of the water-cement ratio, but the expansion rate when the water-cement ratio is 0.6 is smaller than that when the water-cement ratio is 0.4; when the cement content is 600 kg/m³, the expansion rate increases with the water-cement ratio. When the cement content is 800 kg/m³, the expansion rate first increases and then decreases with the increase of the water-cement ratio, but the expansion rate when the water-cement ratio is 0.6 is higher than that of the water-cement ratio. 0.4 hours small. Therefore, the expansion rate as a whole decreases as the water-cement ratio increases. This is because the cement content is relatively reduced, the amount of reactions with aluminum powder are reduced. The gas generation is reduced, and the bubbles are reduced, so the expansion rate is reduced.

![Fig. 2 Volume Change Curve](image)

4.2. Dry density analysis

Table 3 shows the relationship between the 28d compressive strength of each group of test blocks and the corresponding compressive strength values of the dry density and the standard dry density. It can be seen from the table that the water-cement ratio has a greater impact on its dry density, and when the water-cement ratio is low, the dry density is greater; the amount of cement has less effect on its dry density, and has a greater impact on the compressive strength. The compressive strength does not reach 5MPa, but the compressive strength of the configured foam concrete is greater than the corresponding compressive strength of its dry density grade. Consider replacing cement with some other admixtures.

| Serial number | 28d dry density (kg/m³) | Compressive strength range (MPa) | 28d compressive strength (MPa) |
|---------------|-------------------------|---------------------------------|-------------------------------|
| A41           | 752                     | 1.8-3.0                         | 3.92                          |
| A42           | 714                     | 1.2-2.0                         | 3.17                          |
| A51           | 671                     | 1.2-2.0                         | 2.74                          |
| A52           | 544                     | 0.8-1.2                         | 2.33                          |
| A61           | 584                     | 1.0-1.5                         | 2.31                          |
| A62           | 486                     | 0.8-1.2                         | 1.96                          |
| B41           | 737                     | 1.2-2.0                         | 3.52                          |
| B42           | 725                     | 1.2-2.0                         | 2.86                          |
| B51           | 697                     | 1.2-2.0                         | 2.57                          |
| B52           | 575                     | 1.0-1.5                         | 2.02                          |
| B61           | 568                     | 1.0-1.5                         | 2.03                          |
| B62           | 491                     | 0.8-1.2                         | 1.64                          |
| C41           | 776                     | 1.8-3.0                         | 2.98                          |
| C42           | 733                     | 1.2-2.0                         | 2.66                          |
| C51           | 693                     | 1.2-2.0                         | 2.44                          |
4.3. Analysis of Compressive Strength

Figure 3 shows the relationship between the content of aluminum powder and the compressive strength of concrete cubes with different water-cement ratios for the same amount of cement. It can be seen from the figure that when the aluminum powder content is increased from 0.1% to 0.2%, the compressive strength of the cube is reduced by 10-30%. This is because the aluminum powder reacts with water and consumes water, which causes the water used for cement hydration. Reduction; and the increase of aluminum powder leads to the increase of bubbles generated by the reaction, which affects the compressive strength of foam concrete; when the water-cement ratio is 0.5, its strength is 70-85% when the water-cement ratio is 0.4; water-cement ratio when it is 0.6, its strength is 46-65% when the water-cement ratio is 0.4. This is because the water-binder ratio is the main factor affecting the strength of concrete. When the water consumption exceeds the water required for cement hydration, the excess water will harden air holes are formed inside the concrete, which leads to a decrease in the force-bearing area and a decrease in strength. Taking into account the influence of temperature on the initial strength of concrete, the foam concrete with a cement content of 500kg/m³ cement in the mix ratio can reach 85% of the foam concrete with a cement content of 600kg/m³ cement under the same other conditions. The foam concrete with a cement content of 400kg/m³ cement in the mix ratio can reach 70% of the foam concrete with a mix ratio of 600kg/m³ cement under the same other conditions.
5. Conclusion

(1) As the relative content of aluminum powder increases, the compressive strength of foamed concrete with the same amount of cement and water-cement ratio decreases.

(2) As the water-cement ratio increases, the compressive strength of foamed concrete with the same amount of cement, and the same relative content of aluminum powder decreases significantly.

(3) With the decrease of cement content, the compressive strength of foam concrete under the mixing ratio of group B and group C can basically reach 90% and 70% of the compressive strength of group A under the same other conditions.

(4) Under the same other conditions, the expansion rate of foamed concrete increases with the relative content of aluminum powder. However, considering the volume of cementitious material and bubble stability, it is predicted that increasing the relative content of aluminum powder after reaching the peak will be Will reduce the volume expansion rate.

Comprehensively considering the compressive strength, dry density and volume expansion rate of foam concrete under this set of test mix ratios, and it is expected to reach a compressive strength of 5MPa under normal temperature curing, and consider adding other admixtures[7] or adding foam stabilizers and early strength agents to further optimize the mix ratio. It might make foam concrete with good foam stability and excellent compressive strength.

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