Resource Utilization of Waste Mud -- Preparation and Properties of Foamed Concrete

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Abstract. The compressed and dehydrated mud was made into filter cake, and then fly ash, silica fume and cement were added to it to prepare foamed concrete with sodium α-olefin sulfonate as foaming agent. By analysing the changing characteristics of the compressive strength, apparent density, water absorption and microstructure of the foam concrete, the key mechanism of making the foam concrete was analysed in depth. The results show that mud filter cake can improve the comprehensive performance of foamed concrete. The best mix ratio is 20% of mud filter cake, 50% of cement addition, 20% of fly ash, 10% of silica fume, 0.55 of water cement ratio and 55% of foam volume. The compressive strength of foam concrete is 1.6MPa and the apparent density is 660.26kg/m³. The water absorption rate is 23.73%, which accords with China Construction Industry Standard JG / T266-2011. Proper addition of mud filter cake can improve the pore structure and cementing material matrix of foamed concrete, and enhance the strength of foamed concrete. However, too much addition will produce connected pores and cracks, and reduce compressive strength. The results can provide theoretical basis and technical reference for mud resource utilization.

1. Introduction
Mud is an indispensable material in engineering construction. It is often used in the construction of underground diaphragm walls and bored piles [1,2].

At present, the disposal of waste mud is mainly carried out by tanker trucks to transport the mud to the waste slag yard for stacking, this method has low efficiency, high cost, and easy to spill during the transportation process, which has an adverse impact on the road environment [3], and have a greater impact on the progress of the project. At the same time, long-term stacking of mud in the waste slag yard will also have an adverse impact on the surrounding water resources and the construction environment, resulting in environmental pollution problems [4,5]. Therefore, seeking a reliable mud treatment method is of great significance to environmental protection. As a lightweight material, foamed concrete has been widely used in building wall filling materials and other fields[6]. The use of waste mud to make foamed concrete can not only alleviate the environmental pollution caused by waste mud to a certain extent, but also has Important economic value [7,8].

This paper flocculates the waste mud to reduce the water content, then the mud filter cake was obtained by mechanical dehydration. On the basis of flocculating and dewatering the waste mud, the
foam concrete solidification method is used to make the mud filter cake, cement and other glues. The cement material and foam are mixed to prepare foam concrete. The closed pores formed by the foam during curing act as aggregates, which is beneficial to improve the curing strength, to meet the requirements of basic building materials.

2. Materials and Methods

2.1. Experimental Materials
The physical and chemical properties of the waste mud used in the experiment are shown in Table 1. The mud is brown and alkaline, with a relative density of 1.10g/cm³, and a Zeta potential of -26.23mV, it has good stability and is not easy to settle [9]. Among the chemical components of the mud, the content of SiO₂ is the highest. The mud has a high colloid rate, good dispersibility, slow settling speed, a water content of 80.35%, indicating that it takes a long time to achieve the mud-water separation effect in a natural state.

![Figure 1. Particle size distribution of waste mud](image)

As shown in Figure 1, the particle size of waste mud particles is mainly distributed between 1-100um, accounting for 92.60%. In this slurry, particles with a particle size of less than 15um account for about 54.08%, which is difficult to separate mud from water under natural conditions [10]. Therefore, a flocculant can be added to treat the mud to promote the flocculation of small particles and achieve rapid mud-water separation.

![Table 1. Physical and chemical properties of mud.](image)

| Physical properties | Relative density (g/cm³) | Colloid rate(%) | pH | Viscosity (s) | Settling speed (mm/min) | Zeta potential (mV) | Water content (%) |
|---------------------|--------------------------|----------------|----|---------------|-------------------------|--------------------|-----------------|
| Data                | 1.10                     | 73             | 7.16 | 12.67         | 3.20                    | -26.23             | 80.35           |
| Chemical composition| SiO₂ | Al₂O₃ | Fe₂O₃ | K₂O | MgO | CaO | Na₂O | TiO₂ |
| Content (%)         | 60.04 | 21.71 | 7.39 | 3.20 | 2.65 | 2.21 | 1.81 | 0.99 |

2.2. Laboratory apparatus and drugs
Six-axis stirrer (JJ-4), portable turbidity meter (2100Q, Hach), particle and potential measuring instrument (ZEN3600, Malven), Malvern laser particle size analyser (Mastersizer 2000, Malven), compressive strength testing machine (YAW-300E).

Anionic polyacrylamide (12 million molecular weight, analytical grade), sodium α- Sodium alkene sulfonate (analytical grade), cement (P42.5R), Grade II fly ash (120 mesh), silica fume (3000 mesh).
2.3. Experimental methods

2.3.1. Mix ratio of foam concrete. While realizing mud resource utilization, ensuring that the performance of the foamed concrete meets the requirements of relevant specifications, this group of experiments takes 10-50% of mud filter cake, 20-60% of cement, 20% of fly ash, 10% of silica fume, 55% of foam according to the volume and 0.55 of water cement ratio. The specific coordination ratio is shown in Table 2.

| Experiment number | Mud filter cake\(^a\) (%) | Cement\(^a\) (%) | Fly ash\(^a\) (%) | Silica fume\(^a\) (%) | Foam\(^b\) (%) | Water cement ratio\(^b\) |
|-------------------|---------------------------|-----------------|-----------------|---------------------|---------------|------------------------|
| A-1               | 10                        | 60              | 20              | 10                  | 55            | 0.55                   |
| A-2               | 20                        | 50              | 20              | 10                  | 55            | 0.55                   |
| A-3               | 30                        | 40              | 20              | 10                  | 55            | 0.55                   |
| A-4               | 40                        | 30              | 20              | 10                  | 55            | 0.55                   |
| A-5               | 50                        | 20              | 20              | 10                  | 55            | 0.55                   |

\(^a\) Mass ratio.
\(^b\) Volume ratio.

2.3.2. Method for preparing foam concrete. (1) Preparation of mud filter cake: take appropriate mud, use APAM with a concentration of 2‰ for flocculation treatment, flocculate and dehydrate the mud at a ratio of 3:10 with the mud, pass the flocculated mixture through a 200-mesh filter cloth, and take it out after standing for 3 hours. Obtain mud filter cake; (2) Preparation of cementitious material slurry: mix the mud filter cake, cement, fly ash, silica fume and water according to a certain ratio and stir evenly to obtain cementitious material slurry; (3) Prepare foam: mix the foaming agent α-Sodium alkene sulfonate and water in a certain proportion, and then prepare the foam through a high-speed foaming machine; (4) Prepare the test block: mix the cementitious material slurry and foam according to a certain ratio and mix them evenly, then pour them into a 7.0×7.0×7.0 cm mold, and cure for 28 days under standard conditions to obtain a foam concrete test block.

3. result and discussion

3.1. Effect of filter cake admixture on compressive strength

As shown in Figure 2, with the increase of mud cake content, the compressive strength of foam concrete increased first and then decreased. When mud cake content was 10 %, the compressive strength was 1.4 MPa. When the mud cake content increased to 20 %, the compressive strength reached the maximum of 1.6 MPa. However, with the increase of mud cake content, the compressive strength decreased. When the mud cake content was 30 %, the compressive strength decreased to 1.3 MPa. When the mud cake content increased to 50 %, the compressive strength decreased to the minimum value of 0.1 MPa, and the compressive strength was too low. This indicates that the mud cake content cannot enhance the compressive strength of foam concrete. The strength source of foamed concrete is mainly the matrix and pore structure of cementitious materials, which is produced by the support of hardened cementitious materials between pores. When the mud cake content is too high and the cement content is too low, the cementitious effect of cementitious materials is not strong and the compressive strength is reduced. Therefore, when using mud filter cake to make foamed concrete, attention should be paid to the reasonable control of the mud cake content. In summary, it is appropriate to add 10 ~ 30 % mud cake.
3.2. Effect of filter cake addition on apparent density

As shown in Figure 3, the apparent density of foam concrete increases first and then decreases with the increase of mud cake content. When the mud cake content is 10%, the apparent density is 650.70 kg/m³. When the mud cake content increases to 20%, the apparent density increases to the maximum value of 660.26 kg/m³, but with the increase of mud cake content, the apparent density decreases. When the mud cake content increases to 50%, the apparent density decreases to the minimum value of 572.58 kg/m³. The excesses mud cake content will affect the decrease of apparent density, which is mainly due to the fact that mud filter cake is lighter than cement and has porous interior. When the foam is mixed with the slurry of cementitious material, the resistance to bubble expansion becomes smaller, resulting in an increase in foaming height and a decrease in apparent density.

3.3. Effect of filter cake addition on water absorption

As shown in Figure 4, with the increase of the mud cake content, the hygroscopic rate of foam concrete showed a gradual upward trend. When the mud cake content was 10%, the hygroscopic rate was 22.33%. When the mud cake content increased to 30%, the hygroscopic rate increased to 24.18%, with an increase of only 1.85%. However, when the mud cake content increased from 10% to 50%, the hygroscopic rate increased to 27.76%, with an increase of 3.58%. Overall, the change was not significant, and the mud cake content had little effect on water absorption.
3.4. micromorphology analysis

In order to intuitively explain the influence of the mud cake content on the performance of foam concrete, A-2 and A-3 groups of test blocks were selected to conduct microscopic morphology analysis on the pore structure and cementitious material matrix of foam concrete test blocks by scanning electron microscopy. The mix design and performance test results of the two groups of test blocks are shown in Table 3. Among them, the mud cake content of A-2 test block is 20 %, and the compressive strength is 1.6 MPa, which is the largest compressive strength in all test blocks. The mud cake content of A-3 test block is 30 %, and the compressive strength is 1.3 MPa, which is relatively large. A-2 and A-3 can be used as control groups. Through the microscopic morphology analysis of the pore structure and cementitious material matrix of the three groups of test blocks, the influence of mud cake content on the performance of foam concrete was further analyzed.

Table 3. Mix proportion design and performance test results of three groups of test blocks.

| Experiment number | mud filter cake (%) | cement (%) | flyash (%) | silica fume (%) | foam (%) | water cement ratio | compressive strength (MPa) | apparent density (kg/m³) | hygroscopic rate (%) |
|-------------------|---------------------|------------|------------|----------------|----------|-------------------|--------------------------|--------------------------|---------------------|
| A-2               | 20                  | 40         | 20         | 10             | 55       | 0.55              | 1.6                      | 660.26                   | 23.73               |
| A-3               | 30                  | 40         | 20         | 10             | 55       | 0.55              | 1.3                      | 618.03                   | 24.18               |

*a Mass ratio.

*b Volume ratio.

Figure 5 is the micro-morphology of mud cake with 20 % and 30 % content respectively. When the mud filter cake content is 20 %, the pore distribution inside the foam concrete is uniform and the pore size is relatively consistent. The pore size is concentrated in the range of 200 – 300 μm, and most of them are completely closed pores. There are fewer connected pores and incompletely closed pores. The pore wall and the cementitious material matrix are well developed, and no obvious cracks appear.
When the mud filter cake content is 30%, the distribution of pores in foam concrete is relatively uneven, and the pore size is concentrated in the range of 100 – 300 μm. Although most pores are completely closed pores, there are more connected pores and incomplete closed pores. The cementitious material matrix is well developed, and no obvious cracks are found, but some pores have cracks. By comparing and analyzing the micromorphology of two groups of test blocks with 20% (compressive strength: 1.6MPa) and 30% (compressive strength: 1.3MPa) of mud filter cake, it is found that the quality of mud filter cake is lighter than that of cement, and the internal pores are porous. The increase of mud filter cake content leads to the mixing of cementitious materials and foam, which affects the stability of foam, resulting in more connected pores and incomplete closed pores, and then affects the compressive strength of foam concrete. However, due to the low content of mud filter cake, the changes of compressive strength, apparent density and water absorption are not obvious.

4. Conclusion
The compressive strength, apparent density and water absorption of foamed concrete prepared under the mixing ratio of 20% mud filter cake, 50% cement, 20% fly ash, 10% silica fume, 0.55 water-cement ratio and 55% foam volume were 1.6 MPa, 660.26 kg/m³ and 23.73%, respectively, which met China Construction Industry Standard JG/T266-2011.

Appropriate addition of mud filter cake can not only realize the resource utilization of mud filter cake, but also improve the compressive strength of concrete and the performance of foam concrete. However, the excessive addition of mud filter cake will affect the pore structure of foam concrete and the matrix of cementitious materials, produce connected pores and cracks, and reduce the compressive strength. In use, the addition amount should be strictly controlled.

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