Research on Rapid Solidification Cement Asphalt Grouting Plugging Material for Earth and Rock Embankments

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Abstract. At present, there is a shortage of emergency repair materials for dams in small and medium-sized watersheds. This paper studies a cement asphalt composite grouting material aimed at rapid disposal and repair of dam defects in small and medium-sized watersheds. The article conducted experimental research on the proportioning of cement asphalt composite grouting materials, exploring their compressive strength, rheological properties, durability, and impact resistance. Research has shown that by increasing the content of cement in the cement asphalt composite grouting material, the compressive strength of the consolidated material is greatly improved, with a maximum compressive strength of 23.32 MPa. The initial setting time of the material can be adjusted, and the shortest time can be less than 20 minutes. The material has excellent impact resistance and a slurry retention rate of up to 100%. Therefore, the studied cement asphalt composite grouting material is suitable for rapid repair of dam defects in small and medium-sized watersheds.

Keywords: Grouting material; Rapid disposal; Small and medium-sized watersheds; Slurry retention rate.

1 Introduction

Leakage is a common problem in dam groups in small and medium-sized watersheds, and with the long-term operation of dams in small and medium-sized watersheds, this issue is becoming increasingly common. Existing reservoirs (dams) in small and medium-sized watersheds not only cause economic losses, but may also threaten the safety of the entire dam. To avoid the above disasters, the most critical step in addressing the risks of dam groups in small and medium-sized watersheds is to quickly and effectively repair the defects that have occurred. The most critical factor in the repair process is the reliability of the material.

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The principle of conventional grouting plugging (including cement slurry, cement mortar, cement paste and chemical slurry, etc.) is: the slurry is diffused through the grouting pump and filled to the sand gravel pores (or rock fissures) and other places to solidify and harden, forming a grouting stone body (or gel) of certain strength, so as to block the leakage channel, which is mainly achieved through cement hydration or chemical reaction between the main agent of the slurry and the curing agent. Hot asphalt grouting material utilizes the physical properties of asphalt, that is, it becomes a liquid that is easy to flow after heating and a solid after cooling. By controlling the temperature, the material's physical state is adjusted to achieve the purpose of blockage. Asphalt slurry is immiscible with water. When asphalt is heated into a flowing state, the slurry has good fluidity and injectability. After entering the leakage site through the grouting pump, it condenses when encountering water and gradually adheres to the surface of the permeable channel, blocking the leakage channel. Compared to other materials, asphalt slurry has the characteristic of not being diluted or dispersed by water, making it particularly suitable for repairing water leakage in high flow and high-speed dams.

Fuping [1] has developed a low heat asphalt in the "water in oil" state using the principle of first emulsification and then demulsification, which still has good fluidity and pumpability at 70 °C and has been applied in multiple projects. Mohsen [2-4] and others conducted performance tests on low heat asphalt, different material ratios, strength tests, rheological parameter tests, etc. They conducted in-depth research on the material selection, rheological properties, pumpability, demulsification speed, temperature sensitivity, etc. of low heat asphalt, and improved the performance indicators of low heat asphalt materials. However, these indicators are mainly performance indicators of the slurry itself under anhydrous conditions, and there is relatively little research on its flow characteristics in sand and gravel formations, especially on the flow characteristics of low heat asphalt slurry in water rich sand and gravel formations, and there have been no relevant reports. The influencing factors and mechanism of slurry diffusion characteristics are not clear enough, and the rich water environment will have a very adverse impact on the change process of slurry performance and gel characteristics, so it is urgent to carry out relevant research work [5-8]. At present, there is a lack of research on the flow behavior and importance of low heat asphalt slurry under different environmental conditions [9-11].

This paper studies a cement asphalt composite grouting material and explores its compressive strength, rheological properties, durability, and impact resistance. The compressive strength of the material after consolidation can reach up to 23.32 MPa, the initial setting time can be less than 20 minutes, and the slurry retention rate can reach 100%. Therefore, the studied cement asphalt composite grouting material is suitable for rapid repair of dam defects in small and medium-sized watersheds.

2 Materials and Methods

2.1 Material preparation

The commonly used 42.5 ordinary Portland cement is selected for research on cement. Select 90 # hydraulic asphalt as the raw material for low heat asphalt. Choose a medium crack emulsifier as the emulsifier. These materials and other materials are purchased in the market. Heat the asphalt to 70 °C, then add cement for mixing at a mixing rate of 100r/min. The cement asphalt grouting material should be used under heating conditions, and construction should be carried out quickly after heating. The ratio of cement asphalt composite grouting material is as follows:

Table 1. The ratio of cement asphalt composite grouting material

Number	asphalt	Cement	Proportion of additives	Water	Emulsifying agent	Demulsifier
1#	0.6	0.6	0.03	1	0.03	0.01
2#	0.5	0.6	0.03	1	0.03	0.01
3#	0.4	0.6	0.03	1	0.03	0.01

2.2 Characterization

The setting time test shall be conducted in accordance with the "Method for Testing Water Consumption, Setting Time, and Stability of Cement Standard Consistency" (GB/T 1346-2001). The study selected Rheolab QC rotational rheometer for the determination of rheological parameters of rapid setting paste slurry. The compressive strength test of the paste solidified body shall be carried out in accordance with the method of "Testing Method for Strength of Cement Mortar (ISO Method)" (GB/T 17671-1999), using a 40mm × 40mm × 160mm test mold. We processed and made impact resistant experimental models in the laboratory, simulating different boundary conditions with different materials; The water flow pipeline can be combined with multiple pipelines, and different flow velocity and flow conditions can be simulated by starting and stopping different numbers of pumping pumps.

3 Results & Discussion

3.1 Compressive strength performance

The 7 day and 28 day compressive strengths of specimens with different ratios were tested using a compression tester and curing box. The experimental results are shown in the following figure 1.

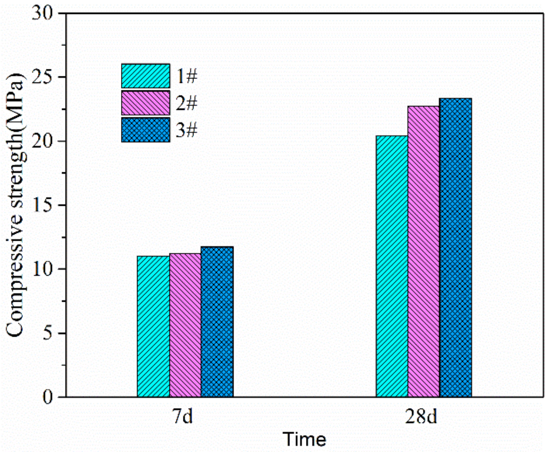

Fig. 1. The compressive strengths of specimens

From the above experimental results, it can be seen that the strength of the three types of cement asphalt composite grouting materials is slightly different. Among them, the compressive strength of 3 # is the highest, which is due to the fact that 3 # has the lowest asphalt content and the highest relative cement content among 1 # to 3 #. The strength of cement asphalt composite grouting material mainly comes from cement. The compressive strength of sample 3 # is the highest, with a compressive strength of 11.74 MPa at 7 days and 23.32 MPa at 28 days.

3.2 Durability performance

3.2.1 Research on frost and thawing resistance.
The dynamic modulus of elasticity can effectively characterize the internal damage of cement asphalt composite grouting materials. Figure 2 (a) shows the change in relative dynamic modulus of elasticity of cement asphalt composite grouting materials after freeze-thaw cycles. From the graph, it can be seen that the dynamic elastic modulus of cement asphalt composite grouting material decreases with the increase of freeze-thaw cycles. After 125 freeze-thaw cycles, the dynamic elastic modulus of sample 1 decreased to 91.6%, while the dynamic elastic modulus of samples 2 and 3 decreased significantly. From samples 1 # to 3 #, it can be seen that sample 1 # has the largest decreasing trend in elastic modulus, while sample 3 # has the smallest decreasing trend. This is because the proportion of asphalt gradually decreases from sample 1 to sample 3, and the elastic modulus of asphalt is much smaller than that of hardened cement material. In addition, freeze-thaw cycles cause greater damage to asphalt materials, so the larger the proportion of asphalt, the greater the loss.

The effect of freeze-thaw cycles on the compressive strength of cement asphalt composite grouting materials is shown in the figure. From the graph, it can be seen that after 125 freeze-thaw cycles, the compressive strength of sample 1 # decreased by a maximum of 45.6%. Under the same number of freeze-thaw cycles, the compressive strength of sample 1 # decreased significantly compared to sample 3 #. This is because the proportion of asphalt in sample 1 # is higher, and freeze-thaw cycles have a greater impact on it. Samples with a higher proportion of asphalt have a higher degree of pre compression loss.

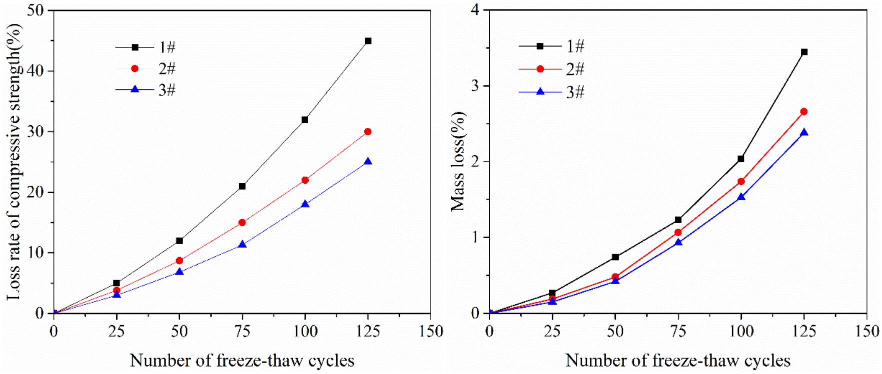

Fig. 2. Compressive strength loss (a) and mass loss of specimens under different freeze-thaw cycles

3.2.2 Corrosion resistance performance.

From Figure 3 (a), it can be seen that the relative dynamic elastic modulus of samples 1 #~3 # increases with the increase of soaking days in sulfate solution, and then decreases. This is because during the initial soaking stage, hydration products react with sodium sulfate to produce calcium sulfate and ettringite, filling the gaps inside the material and increasing its density. Therefore, the compressive strength of the material shows an upward trend. But as the soaking time increases, the formed calcium sulfate and ettringite will promote the expansion of the material body, destroy the compactness of the internal structure of the material, and thus lead to a decrease in compressive strength. The increase in cement content from 1 # to 3 # results in a greater impact of sulfate solution on the material.

From Figure 3 (b), it can be seen that the relative dynamic modulus of the material also shows a trend of first increasing and then decreasing. This is also due to the reaction between hydration products and sulfates, which leads to a denser internal structure of the material. But as the reaction progresses, it will cause the internal structure of the material to expand, thereby damaging the density of the material, which will further lead to a downward trend.

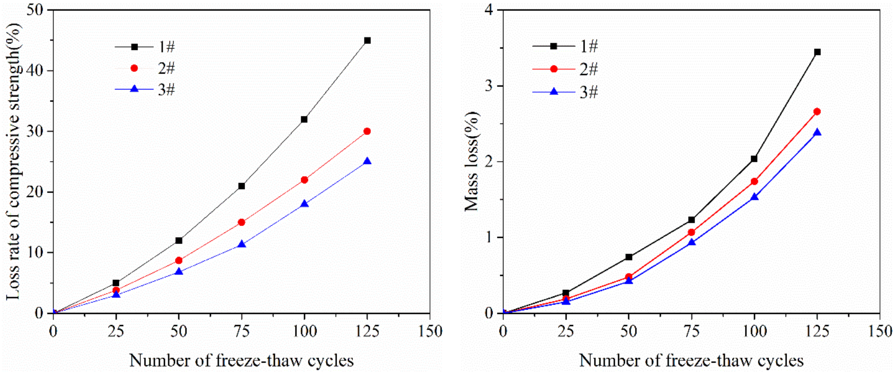

Fig. 3. Changes in compressive strength (a) and relative elastic modulus of specimens (b) under different soaking days

3.3 Anti impact test of cement asphalt composite grouting material

The grouting situation was analyzed experimentally, and the experimental process is shown in Figure 4.

Fig. 4. Anti impact test process

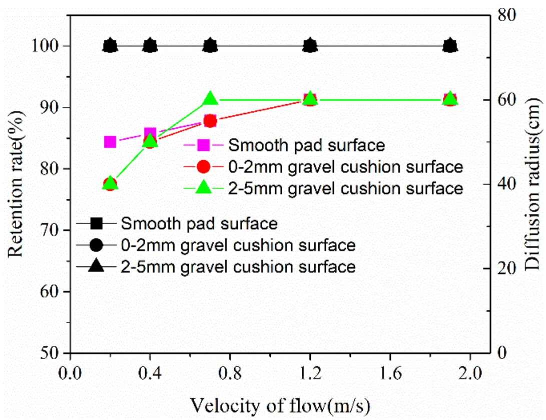

Fig. 5. Retention rate and diffusion radius of slurry under different flow rate conditions

According to the results of the impact test, from Figure 5, the low heat asphalt grouting material has a good retention rate of slurry during the impact test, and there is no loss of asphalt material in multiple sets of tests, and the sealing effect is good. Moreover, under different flow rates and underlying surface conditions, the diffusion distance of low heat asphalt slurry is not significantly different, all around 60cm.

4 Conclusions

(1) The cement asphalt composite grouting material of sample 3 has the highest compressive strength, with a compressive strength of 11.74 MPa at 7 days and 23.32 MPa at 28 days.
(2) Under different dynamic water conditions, the retention rate of cement asphalt composite grouting material slurry is 100%, and the farthest diffusion distance of the slurry can reach 60cm.
(3) Cement asphalt composite grouting material has good durability. It can be applied in emergency restoration of many small and medium-sized watersheds.

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