Study on Development of High Belite Sulphoaluminate Cement-Based Grouting Material

Abdulfattah Atiq¹, Shwei Niu², Han Pengju³*

¹ Postgraduate Student, Department of Geotechnical Engineering, Taiyuan University of Technology
² Doctoral Student, Department of Geotechnical Engineering, Taiyuan University of Technology
³ Professor, Department of Geotechnical Engineering, Taiyuan University of Technology

ABSTRACT

As a new type of grouting material, the research on the performance and hydration mechanism of High Belite Sulphoaluminate cement grouting material is not enough, and it is difficult to adjust the slurry performance according to different grouting conditions, which leads to some difficulties in the application of High Belite Sulphoaluminate cement grouting material in engineering practice. Therefore, in this paper, the performance and hydration mechanism of High Belite Sulphoaluminate mud based grouting material are systematically and comprehensively studied to provide basic guarantee for its further application and overview of grouting method. In view of the problems existing in the composite application of High Belite Sulphoaluminate cement, by adjusting the system of the mineral composition, which is the introduction of coal metakaolin (CMK) and ordinary Portland cement (OPC), to develop a new type of grouting material of hydration reaction rate gradient, and the physical mechanical properties and durability of the grouting material for the experimental study of the system, and at the same time, the slurry diffusion law of the material was studied by numerical simulation.

Keywords: ICT, KNOWLEDGE SOCIETY, LITERATURE REVIEW, MOBILE LEARNING, MULTIMEDIA MOBILE DEVICES

1. Aim of the research

At present, Portland cement grouting material is widely used in grouting engineering due to its low cost, wide source of raw materials, simple construction technology and other characteristics, and its demand trend will continue to grow, which will bring adverse effects on the green development of cement industry. Therefore, in order to achieve the development goals of "low-carbon environmental protection" and "energy conservation and emission reduction" in the cement industry, Portland cement grouting materials are bound to be replaced by green grouting materials. Among them, High Belite Sulphoaluminate cement grouting material is one of the development trends of grouting materials in the future.

2. Introduction

Grouting method refers to the use of air pressure or hydraulic pressure and other methods to inject the
solidified slurry into the cracks or pores of rock and soil through grouting pump, so as to occupy the space of water and gas in rock and soil particles or cracks of rock and soil, so as to improve the physical and mechanical properties of rock and soil. Through cementation, filling, compaction and skeleton function, geotechnical engineering grouting can achieve the following purposes:

1. Improve the rock and soil that do not meet the engineering requirements
2. Prevent or control hydrogeological disasters

In 1802, grouting method was first applied in France, which has a history of more than 200 years. At present, grouting method is widely used in mining, tunnel, water conservancy, construction and other engineering fields. With the development of science and technology, grouting method has developed into a new interdisciplinary application subject, mainly involving chemical engineering, environmental engineering, material engineering, geotechnical engineering and testing technology. The development of grouting method can be roughly divided into four stages: original clay grouting stage, primary cement grouting stage, intermediate chemical grouting stage and modern grouting stage.

3. Test material and methods

3.1 Cement as material

High Belite Sulphoaluminate cements (HBSC) and ordinary Portland cement (OPC) was used in the test. Among them, High Belite Sulphoaluminate cement is produced by Tangshan polar bear building materials Co., Ltd., with strength grade of 42.5; ordinary Portland cement is produced by Taiyuan Shitou Cement Co., Ltd., with strength grade of 42.5. The test results of cement particle size distribution are shown in Figure 3.1. Among them, the particle size of High Belite Sulphoaluminate cement is mainly distributed in the range of 2-15 μm, with an average particle size of 9.96 μm; the particle size of ordinary Portland cement is mainly distributed in the range of 5-20 μm, with an average particle size of 14.85 μm. The chemical composition of cement is shown in Table 3.1; the mineral composition of cement is shown in Figure 3.2.
## Table 3.1: Chemical composition of cement

<table>
<thead>
<tr>
<th>Chemical composition (%)</th>
<th>CaO</th>
<th>SiO2</th>
<th>Al2O3</th>
<th>Fe2O3</th>
<th>MgO</th>
<th>SO3</th>
<th>K2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBSC</td>
<td>50.74</td>
<td>13.98</td>
<td>18.59</td>
<td>2.02</td>
<td>2.15</td>
<td>11.75</td>
<td>0.21</td>
</tr>
<tr>
<td>OPC</td>
<td>66.35</td>
<td>18.81</td>
<td>5.86</td>
<td>3.34</td>
<td>1.04</td>
<td>2.53</td>
<td>0.41</td>
</tr>
</tbody>
</table>

3.2 Stability test

Stability refers to the degree of uniformity change of slurry after its flow speed slows down and completely stands, and it is the time length to maintain its original dispersion and fluidity [60] [61]. It is considered that the smaller the water separation rate is, the better the stability is. $W / C = 1.5$ is selected.
Test instrument: 1000ml measuring cylinder.

Test method: after the preparation of slurry, 1000 ml slurry is injected into the measuring cylinder; the volume of precipitated water is measured after standing for 2 h. In order to reduce the evaporation of water during the test, the glass plate was covered on the measuring cylinder.

3.3 SEM Analysis test

Scanning electron microscope (SEM) is used to obtain microstructure image by secondary electron reflection focusing imaging [67]. Scanning electron microscope (SEM) has become one of the most commonly used methods to study the micro morphology of cement hydration products due to its nano scale imaging, wide range of image magnification, high separation rate and multi angle observation of spatial rotation and translation.

Test instrument: Hitachi tm-3000 desktop scanning electron microscope.

Test method: SEM sample breaking is consistent with the termination of hydration treatment and XRD. Take small samples that have been terminated hydration treatment, grind them into 2cm × 2cm × 1cm cuboid on different fineness sandpaper, and dry them in 40 °C oven for 12h. In addition, in order to eliminate the charge, it is necessary to vacuum gold plating on the surface of the test block. The vacuum degree of gold plating is 5-6pa, and the plasma current is less than 10mA.

4. Results & Analysis

4.1 Stability test for mechanical properties

In grouting engineering, grouting materials can be divided into two categories: stable grout and unstable grout. Lombardi, a scholar, put forward that the slurry with water separation rate less than 5% after standing for 2 h can be regarded as stable slurry, and this is the standard for the classification of slurry types. The indirect measurement method is used to distinguish the advantages and disadvantages of slurry stability, that is, the smaller the water separation rate is, and the better the stability is. According to the uniform test results, the water separation rates of slurry with different proportions are obtained, as shown in Figure 4.1.
Figure 4.1: Water-bleeding ratio of slurry in different ratio

It can be seen from the figure that there are great differences in the water separation rate of different proportions of slurry. The water separation rate of p17 is the lowest, 1.1%, and that of P5 is the highest, 12.7%, which is 11 times higher than that of p17. In all the experimental proportions, there are 11 groups of slurry whose water separation rate is less than 5%, which belongs to stable slurry. Among them, there are 4 groups with water separation rate between 1% and 2%, 5 groups with water separation rate between 2% and 3%, and 1 group with water separation rate between 3% and 4% and 5% respectively. In addition, the water separation rate of 7 groups of slurry is more than 5%, which belongs to unstable slurry, and the water separation rate is about 10%.

According to the regression equation, the influence order of each component on the water evolution rate (y) of slurry is coal measure metakaolin (x3), High Belite Sulphoaluminate cement (x1) and ordinary Portland cement (x2). That is to say, coal measures metakaolin is the most important factor affecting the water drainage rate of slurry, and it is negatively correlated; followed by High Belite Sulphoaluminate cement, which is also negatively correlated; while ordinary Portland cement has little effect on the water drainage rate of slurry. Therefore, in the case of large proportion of metakaolin in coal measures, the cement slurry has
almost no water separation, low water separation rate and good stability. However, in the case of ordinary Portland cement, the cement slurry has serious water separation, high water separation rate and poor stability. However, if the water precipitation rate is too low, the plastic viscosity of the slurry will be very large, it will reach the initial setting state in a short time, and the rheological property is poor, thus reducing the effective diffusion distance of the slurry.

In the process of testing the water separation rate, it is found that the water separation rate has a certain influence on the strength of the stone body. During the standing time, the slurry with large water separation rate has serious sedimentation and volume compression, which makes great difference in the homogeneity of the stone body. The concrete performance is as follows: due to the sedimentation and water separation, the density of the upper slurry is low, which leads to the stratification of the stone body, and then the adhesion between the slurry and the injected body is poor, and the strength of the stone body is low; at the same time, due to the sedimentation and water separation, the density of the upper slurry is low, which leads to the stratification of the stone body. Because of the compression, the density of the lower slurry is higher, and the strength of the stone body is also higher. Therefore, the strength of the stone body of the slurry is anisotropic, which is very disadvantageous to the reinforcement and sealing of rock and soil. Therefore, it is very important to choose the slurry grouting with good stability.

4.2 SEM analysis of Hydration mechanism

The properties of cement materials are not only related to the composition of hydration products, but also depend on the microstructure of hydration products to a great extent. Figure 4.2 and Figure 4.3 show the SEM and EDS spectra of cement materials at different hydration time.

In the early stage of hydration (a), a large number of acicular aft phase, hexagonal flake AFM phase and cement clinker particles were formed. With the advance of the hydration process (b), the six square sheet of AFm phase gradually increased, the fibrous C-S-H gel appeared, and the C-S-H gel filled in the network structure pore of the AFt phase, which made the material structure become dense. The acicular ait phase began to transform into coarse acicular and columnar structure, indicating that with the progress of hydration, the development of ait phase became more and more complete and the structure became more compact. At the same time, it is difficult to find CH phase in SEM, which indicates that there is little or no CH phase in the hydration products, which is consistent with the previous XRD results.
Figure 4.2: SEM morphology of cement-based material with early hydration stage

The hydration of cement materials continued for 14 days (c), the hydration reaction was more complete, the number of hydration products was further increased, and the microstructure became denser. At the later stage of hydration (d), the aft phase is well developed into columnar and rod-shaped, interpenetrating between hexagonal lamellar AFM phases, and columnar and rod-shaped aft phases interpenetrating with each other to form a network, so that the pores between them decrease with the increase of aft. At the same time, with the hydration of C2S in the late stage, fibrous and layered C-S-H gel was formed, which overlapped with the early hydration AFm and filled the pores between AFt phases, which further compacted the microstructure of cement materials. At this stage, the gel phase constitutes the main body of the cement stone body, while the AFt phase interspersed in the gel phase greatly reduces the porosity of the material and is conducive to the growth of the strength of the system. At the same time, it is still difficult to find ch phase in the later stage of hydration, because CH phase is involved in the hydration reaction, so the existence of CH phase cannot be observed. That is to say, there is little or no CH content in the hydration products during the whole hydration stage.
In addition, the AH3 amorphous phase of the velvet globule can also be observed from the diagram. With the hydration process, the hydrated products gradually increase, and Ettringite interacts with each other to form a framework. This POM like AH3 gel products are filled in the skeleton, which play the role of caulking and cementation. The porosity of hardened cement paste decreases and the microstructure becomes...
denser. Cement paste has excellent mechanical properties.

4.3 SEM analysis for durability

Figure 4.4 shows the SEM morphology and EDS spectrum of the corrosion products of the test block (D-4) immersed in single sulfate. It can be seen from the diagram that after a single sulfate attack, there is a large number of needle like erosion products in the pores of the test block, with a length of about 1~2 m, which interspersed in the layered C-S-H gel, and the microstructure of the material becomes dense. In addition, cracks can also be found around the holes, so it is considered that the needles like corrosion products in the holes are the source of the failure of the test block. According to EDS analysis, Ettringite is the main reason of single sulfate corrosion.

![SEM morphology of erosion products soaked in sulfate solution](image1)

![EDS spectrum of corrosion products](image2)

Figure 4.4: SEM morphology of erosion products soaked in sulfate solution

5. Conclusion

High Belite Sulphoaluminate cement has become one of the hot spots of cement material research in recent years and the development trend of grouting materials in the future due to its low energy and resource consumption and low CO2 emission in the preparation process. This topic mainly focuses on the problems existing in the composite application of High Belite Sulphoaluminate cement, and carries out in-depth
research from the development of grouting materials and slurry diffusion plugging law. Based on the study of physical and mechanical properties, the composition and microstructure of hydration products were studied by SEM. Under the condition of still water, no matter cement slurry or hoc grouting material, the slurry diffusion shape is round, and the pressure at the same time is attenuated on its diffusion radius, while the pressure at the same position increases with the grouting time.

References


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