

PAPER • OPEN ACCESS

Study on Performance of Grouting Fluid Mixed with Clay-Steel Slag Powder

To cite this article: Yinping Qi *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **693** 012116

View the [article online](#) for updates and enhancements.

You may also like

- [Fabrication of an oil–water separation copper filter using laser beam machining](#)
Kyoung Ho Ha and Chong Nam Chu
- [Flow length-dependent evaluation of separation and concentration functions of microfluidic chips for allergy testing using pseudo-cells](#)
Shunsuke Shinuchi, Koichiro Kobayashi, Yuhki Yanase *et al.*
- [pH-sensitive organic diimide materials-based superhydrophobic surface for oil-water separation applications](#)
K Khanmohammadi Chenab, B Sohrabi and M Esrafil



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Study on Performance of Grouting Fluid Mixed with Clay-Steel Slag Powder

Yinping Qi¹, Qingjiang Wang^{2,*}, Zhenzhen Sun² and Xugong Wang²

¹Shandong Zhengyuan Geological Resources Exploration Co., Ltd., Jinan, Shandong 250101, China

²College of Civil Engineering and Architecture, Shandong University of Science and Technology, Qingdao, Shandong 266590, China.

*Email: chinatsingj@163.com

Abstract. By designing orthogonal experiments, mixing different amounts of clay, steel slag powder and polycarboxylic acid water-reducing agent into ordinary Portland cement, prepare grouting liquid according to different water-cement ratios, and analyze the grouting liquid under standard curing conditions. Fluidity and water separation. The test results show that: with the increase of the clay content, the fluidity and water separation rate of the slurry gradually increase. As the content of steel slag powder increases, the fluidity first increases and then decreases, but the overall trend is increasing, and the water separation rate increases.

1. Introduction

Steel slag is a waste produced in the process of steel smelting. At present, a large amount of steel slag is produced in my country every year, but the utilization rate of steel slag is very low [1]. The main mineral composition of steel slag powder is similar to that of Portland cement clinker and has good gelling properties. If steel slag can be added to Portland cement as a grouting material, it will not only realize the reuse of waste steel slag resources, And to a certain extent can improve the performance of grouting materials. The main mineral components of steel slag are tricalcium silicate, dicalcium silicate, forsterite, calcium ferroaluminate and other substances with hydration activity, which can not only reduce cement production costs, but also improve cement performance [2]. Clay is mainly composed of extremely fine-grained crystalline minerals. Clay has low hardness and has strong adsorption, plasticity and fire resistance. Due to the wide range of clay sources and low cost, it can be widely used in grouting and water blocking in engineering, especially in the aspects of engineering anti-seepage and water blocking. Scholars at home and abroad have conducted a lot of research on steel slag powder and clay. Futian Liu [3] and others have used steel slag and cement clinker as the main raw materials and found that the early strength of cementitious materials can be improved by adding an activator. Xiaowei Sun [4] and other studies found that the hydration activity of steel slag is low, and there are few pre-hydration products. Xiaofeng Peng [5] and others prepared clay to prepare composite materials, and indicated that the modified materials can be used for building bricks and roadbeds. However, there are still few researches on grouting materials mixed with clay and steel slag powder.

Therefore, this subject mainly studies the influence of clay content and steel slag powder mixing on the fluidity and water separation rate of grouting materials, which can provide empirical reference for the comprehensive utilization of clay and steel slag in grouting materials.



2. Test Materials and Test Methods

2.1. Experimental Materials

The cement is selected from the PO42.5 grade cement produced by Shandong Shanshui Cement Group Co., Ltd.; the test water is tap water; the test clay is selected from the sodium bentonite produced by Henan Platinum Casting Material Co., Ltd.; the steel slag powder is produced from the Lijing Mine of Lingshou County, Hebei The product processing plant has a specific surface area of 400m²/kg; the water-reducing agent uses polycarboxylic acid high-efficiency powdered water-reducing agent.

2.2. Experiment Method

(1) Fluidity measurement is carried out in accordance with the specification "Technical Specification for Application of Cement-based Grouting Materials" (GB/T 50448-2015). Place the truncated cone mold on a horizontal glass plate. Lift the truncated cone mold smoothly to allow the slurry to flow freely until it stops without disturbance. Use a vernier caliper to measure the maximum diffusion diameter and vertical diameter of the slurry, and take the average value as the initial fluidity value. The result is accurate to 0.1mm.

(2) Water separation rate The water separation rate refers to the percentage of the volume of the slurry water after the slurry is stabilized to the original volume of the slurry. The calculation formula is $\Phi = (100 - h) / 100$, and h is the distance between the precipitated water and the condensed slurry. Using a 250ml graduated cylinder, pour the slurry into the graduated cylinder for water retention treatment, curing at room temperature for 2 hours, and measuring the water separation rate.

2.3. Test Plan Design

The orthogonal experiment method can reduce the workload and analyze the influence of various factors. Four levels of factors are selected: clay content, steel slag powder content, water-reducing agent content, and water-cement ratio, and three levels are determined for each group based on the research experience of relevant material ratios. Design the mix ratio according to the orthogonal experiment rule, see Table 1.

Table 1. Experimental mix ratio

Label	Horizontal combination	A clay/%	B Steel slag powder/%	C Water reducing agent/%	D Water-cement ratio
1	A1B1C1D1	5	10	0.2	0.5
2	A1B2C2D2	5	20	0.4	0.6
3	A1B3C3D3	5	30	0.6	0.7
4	A2B1C2D3	10	10	0.4	0.7
5	A2B2C3D1	10	20	0.6	0.5
6	A2B3C1D2	10	30	0.2	0.6
7	A3B1C3D2	15	10	0.6	0.6
8	A3B2C1D3	15	20	0.2	0.7
9	A3B3C2D1	15	30	0.4	0.5

3. Test Results and Analysis

3.1. Test Results

Through the orthogonal test, the stone rate of 9 groups of grouting solutions and the strength of the consolidated bodies of different ages were obtained. The test results are shown in Table 2.

Table 2. Orthogonal test results

Label	Liquidity (cm)	Water separation rate (%)
1	12.45	3.4
2	26.20	6.0
3	26.35	18.1
4	25.45	4.9
5	17.55	5.7
6	20.45	3.9
7	18.90	4.4
8	27.10	4.8
9	10.45	2.4

3.2. Analysis of the Influence of Slurry Fluidity

The fluidity of the grouting material determines the quality of the grouting effect. In actual engineering, the grout must have good fluidity to ensure that the grout can flow into the pores of the soil and ensure the effect of grouting and reinforcement. Table 3 shows the range analysis of the fluidity of the slurry prepared in the test.

Table 3. Range analysis table for stone rate

Test index	Clay	Steel slag powder	Water reducing agent	Water-cement ratio
K1	21.67	18.93	20.00	13.48
K2	21.15	23.62	20.70	21.85
K3	18.82	19.08	20.93	26.30
R	2.85	4.68	0.93	12.82
Influence	Water-cement ratio > Steel slag powder > Clay > Water reducing agent			

As shown in Table 3, the water-cement ratio has the greatest influence on the fluidity of the slurry, the influence of steel slag powder and clay on the fluidity of the slurry is ranked second, and the water-reducing agent has less influence on the fluidity of the slurry. The influence of various factors on the fluidity of the slurry is shown in Figure 1.

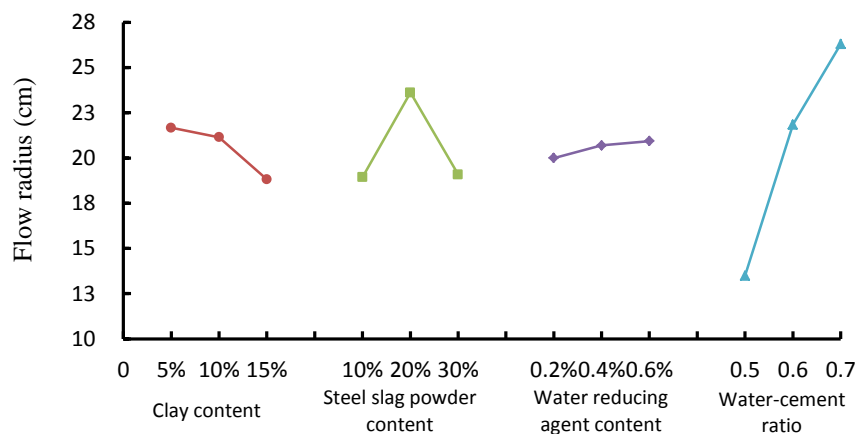


Figure 1. The influence curve of various factors on liquidity

Analysis of Figure 1 shows that as the water-cement ratio increases, the slurry flow radius increases and the fluidity becomes better. This is because when the amount of water in the slurry increases, the cementitious material in the slurry is more fully hydrated, which slows down the flocculation of hydrated particles, and at the same time, the water plays a lubricating effect on the slurry and reduces the resistance when the slurry flows. With the increase of steel slag powder, the fluidity of the slurry first increases and then decreases. The particle size of steel slag powder is smaller than that of cement, and its particles can penetrate into the cement pores and replace the water in the cement pores, thus increasing the fluidity of the slurry. As the content continues to increase, due to the large specific surface area of the steel slag powder, the surface energy state of the steel slag is high, and its surface will absorb a large amount of free water, which will reduce the fluidity of the slurry. As the amount of water reducing agent increases, the fluidity of the slurry decreases. This is because the water reducing agent particles are adsorbed on the surface of the cement slurry to disperse the cement particles and release more free water, which can improve the fluidity of the slurry. As the output of clay increases, the fluidity of the slurry decreases significantly. After the clay is mixed with water, the particle charge and the hydration products in the slurry undergo an ion exchange reaction, which makes the clay more fully hydrated, increases the hydration products, and reduces the fluidity of the slurry.

3.3. Analysis of the Influence of Slurry Water Separation Rate

The water separation rate of the grouting liquid is an important indicator of the stability of the grouting material. The lower water separation rate means that the solidification rate of the grout consolidated body is higher, and the structure is more dense after grouting reinforcement. The range analysis table of the water separation rate of the slurry is shown in Table 4.

Table 4. Range analysis table of water separation rate

Test index	Clay	Steel slag powder	Water reducing agent	Water-cement ratio
K1	9.17	4.23	4.03	3.83
K2	4.83	5.50	4.43	4.77
K3	3.87	8.13	9.40	9.27
R	5.30	3.90	5.37	5.43
Influence	Water-cement ratio > Water reducing agent > Clay > Steel slag powder			

It can be seen from the range analysis that the water-cement ratio has a greater influence on the water separation rate of the slurry. The influence of the water-reducing agent and clay content on the water separation rate of the slurry is ranked second, and the steel slag powder content has the least

effect on the water separation rate of the slurry. . The influence of various factors on the water separation rate of the slurry is shown in Figure 2.

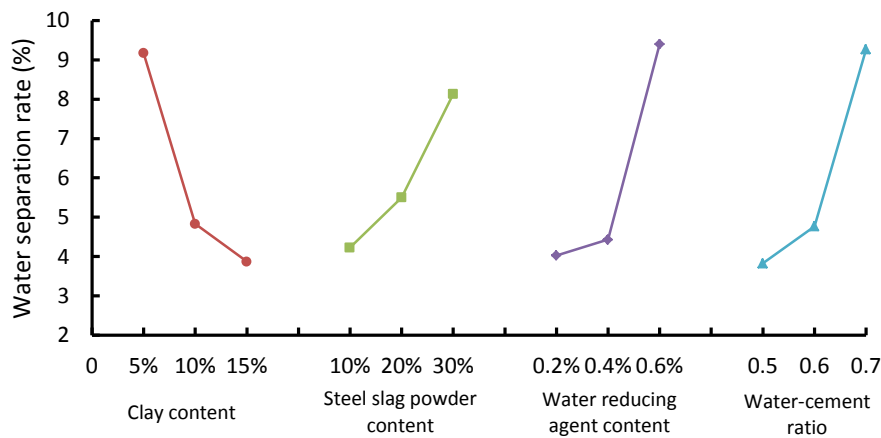


Figure 2. The influence curve of each factor on water separation rate

It can be seen from Figure 2 that the water separation rate of each group of grouting liquid fluctuates greatly, and after the water-cement ratio is 0.6, the water separation rate increases, indicating that the water in the slurry reaches the water required for the hydration reaction. The water rate has increased significantly. The water separation rate of the slurry is proportional to the water-cement ratio, the amount of water reducing agent and the amount of steel slag powder, and inversely proportional to the amount of clay.

As the water-cement ratio increases, the water content in the slurry increases, and the surface layer of the slurry that does not participate in the hydration reaction in the slurry rises, which increases the water separation rate of the slurry. The particle molecules of polycarboxylate water-reducing agent can be adsorbed to the surface of cement particles, breaking the flocculation between cement particles through electrostatic repulsion, dispersing the cement particles, reducing the thickness of the water layer on the surface of the cementitious material, releasing part of free water, causing the slurry to separate out. The rate rises. The particle size of steel slag powder is small, and the water contained in the pores can be replaced by filling the pores of cementitious materials. In addition, the activity of steel slag powder is lower than that of cement and clay. The more steel slag powder is added, the less water is consumed for hydration. Increase the water separation rate. When the clay meets with water, the particles disperse and form a colloid, which can adsorb cement particles, promote mutual catalysis between itself and cement, make the cementitious material more fully hydrated, and reduce the water separation rate of the slurry.

4. Conclusion

Adding clay can reduce the water separation rate of the grouting material, make the cement hydration more fully, and the slurry performance is more stable, but it will reduce the fluidity of the slurry. An increase in the amount of steel slag powder will result in an increase in the water separation rate and fluidity of the slurry.

The water-cement ratio and water-reducing agent increase the fluidity and water separation rate of the slurry. The water-cement ratio and the amount of water-reducing agent should be determined according to actual engineering needs.

5. References

- [1] Shiran Zhao, Kaifeng Zhang, Guofeng Jiao et al. Experimental research on the influence of steel slag-slag composite cementitious material on the performance of mortar[J]. Bulletin of the Chinese Ceramic Society, 2015, 34(S1): 308-313.

- [2] Fahong Wu, Jianming Yang, Lei Cui ,et al. The influence of steel slag powder and fly ash on the salt and freezing resistance of potassium magnesium phosphate cement[J].Journal of Building Materials,2018,21(06):877-885.
- [3] Tongsheng Zhang, Futian Liu, Yikai Li, et al. The effect of activator on the properties of steel slag cementitious materials[J].Journal of Building Materials,2008(04):469-474.
- [4] Xiaowei Sun, Dianping Li, Pengcheng Xu. Experimental research on steel slag-fly ash based composite Portland cement[J].Concrete,2016(09):72-75.
- [5] Xiaofeng Peng, Shuncheng Song. Preparation and mechanical properties of clay-cement composite materials[J].Science Technology and Engineering,2020,20(25):10433-10436.
- [6] Yankai Wu, Xiaolong Qiao, Xinbao Yu, et al. Study on Properties of Expansive Soil Improved by Steel Slag Powder and Cement under Freeze-Thaw Cycles. 2020, :1-12.
- [7] Tian Wang, Kai Wu, Min Wu. Development of green binder systems based on flue gas desulfurization gypsum and fly ash incorporating slag or steel slag powders. 2020, 265
- [8] Tu Sheng He, Yang Xu, Yang Liu, et al. Influence of Fineness and Vontent of Steel Slag Powder on Properties of Composite Admixture. 2020, 6053:117-122.
- [9] Zhifeng Xiao, Meizhu Chen, Shaopeng Wu, et al. Moisture Susceptibility Evaluation of Asphalt Mixtures Containing Steel Slag Powder as Filler. 2019, 12(19).
- [10] Jinsheng Lei, Kang Dai, Baolin Tu, et al. Experimental study on the expansion performance of cement-clay paste with expansion agent[J]. Journal of China Three Gorges University (Natural Science Edition), 2019, 41(06): 54-58.
- [11] Tao Li, Ying Gao, Peng Zhang, et al. Modification of grouting material for clay base plate in deep mining under pressure[J]. Metal Mine, 2019(12): 173-177.