Study on performance of fly ash slag cement grouting materials

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Abstract: In view of the high cost of the existing grouting materials, and at the same time the industrial production of a large number of fly ash, slag and other industrial waste can’t be effectively used. In this paper, the properties of fly ash slag cement with different ratios were studied through laboratory tests. Results show that the cement content in given conditions, with the increase of dosage of fly ash, initial setting and final setting time of cement paste with slow growth, the fluidity is growing, but the stone rate has obvious drop, on the compressive strength, the higher the slag content, is the early compressive strength, the greater the and the higher the dosage of fly ash, the late strength of cement paste were higher. This kind of grouting material has good working performance, can guarantee the project construction needs at the same time save cost, protect the environment.

1. Introduction
At present, the pace of infrastructure construction in various regions is accelerating, and the different soil quality in different regions will often bring non-negligible influence to the project construction, which determines the safety of the building, such as soft clay region, collapsible loess region, saline soil region, so it is very important to deal with these special soil. At the same time, with the acceleration of the process of industrialization, the amount of industrial waste produced in various places is also rising sharply, such as fly ash, slag, the disordered discharge of a large number of, resulting in serious environmental pollution. Therefore, the rational use of these industrial wastes in the construction field, grouting reinforcement materials, will become a good idea.

Many scholars have conducted a thorough research, using industrial waste materials to reinforce grouting material for coal mine goaf[1-3], for such performance parameters of the grouting material for a lot of experimental analysis, prove the feasibility of it as grouting material[4-8], and for the hydration process of fly ash slag cement grouting material has many conclusion[9-11].Based on the predecessors, this paper studied the properties of grouting materials and studied the fly ash slag cement grouting materials under different dosage conditions to find the best ratio.

2. Experiment

2.1 Experimental material
The test uses ordinary #425 Portland cement with a specific surface area of 357m²/kg, fly ash with a specific surface area of 420m²/kg, slag with S95 grade slag with a specific surface area of 530m²/kg, ordinary tap water and water glass with a modulus of 3.3. The chemical composition of fly ash and slag is shown in the following table.
2.2 Experimental scheme
In the previous studies of many scholars, it has been known that the best effect is achieved when the sodium silicate content is 3%. Therefore, the test scheme is as follows:

| Tab.3 | Mix proportion design scheme |
|-------|-----------------------------|
| Formula | water cement ratio | cement content | Industrial waste content (flyash: slag) | Liquid sodium silicate to cement mass ratio |
| Water + cement + fly ash + slag + Liquid sodium silicate | 0.6~1.0 | 20% | 20%: 60%~60%: 20% | 3% |

2.3 Experimental method
The initial setting time, final setting time, fluidity and stone rate of the slurry with the above ratios were tested and determined. Before the compressive strength measurement, the prepared slurry was first poured into the standard cement mold and placed for 24h. Then the slurry was removed from the mold and sent to the standard curing room for curing for 3d, 7d and 28d respectively. Finally, the slurry of fly ash and slag with different content was scanned by microscopic electron microscope.

3. Results and discussion

3.1 Effects of different conditions on compressive strength
In this test, the compressive strength of cement slurry material test blocks with different water-cement ratio, different proportion of fly ash, slag content and different ages were tested. The test results are as follows:

| Tab.4 | 0.6 water-cement ratio the compressive strength of slag cement grouting material |
|-------|---------------------------------|
| Mix proportion/% | Compressive strength/MPa |
| Slag | Fly ash | 3 d | 7 d | 28 d |
| 60 | 20 | 3.3 | 5.2 | 7.9 |
| 50 | 30 | 3.2 | 5.0 | 8.3 |
| 40 | 40 | 3.0 | 4.9 | 8.7 |
| 30 | 50 | 2.8 | 4.7 | 9.1 |
| 20 | 60 | 2.6 | 4.6 | 9.5 |

| Tab.5 | 0.7 water-cement ratio the compressive strength of slag cement grouting material |
|-------|---------------------------------|
| Mix proportion/% | Compressive strength/MPa |
| Slag | Fly ash | 3 d | 7 d | 28 d |


60 20  2.0  3.3  5.5
50 30  1.8  3.2  5.7
40 40  1.7  3.0  6.0
30 50  1.5  2.9  6.5
20 60  1.4  2.8  6.9

Tab.6  0.8 water-cement ratio the compressive strength of slag cement grouting material

| Mix proportion/% | Compressive strength/MPa |
|------------------|--------------------------|
| Slag  Fly ash    | 3 d  | 7 d  | 28 d |
| 60  20           | 1.5  | 1.9  | 3.8  |
| 50  30           | 1.4  | 1.8  | 4.0  |
| 40  40           | 1.2  | 1.7  | 4.1  |
| 30  50           | 1.1  | 1.7  | 4.3  |
| 20  60           | 1.0  | 1.5  | 4.7  |

According to the data in the above table, the compressive strength of slurry at different ages and ratios is quite different. Under the condition of different water-cement ratio, with the same curing time and the increase of water-cement ratio, the compressive strength decreases significantly. Under the condition of the same water cement ratio and different dosage of fly ash slag ratio effects on compressive strength, and the influence relation with ages is very obvious, in the early days of slurry condensation, the higher the slag content, the higher the compressive strength of cement paste, and with the increase of fly ash content, compressive strength of cement paste has gradually reduce, but in the mid-late slurry condensation, the higher the content of fly ash, the greater the compressive strength of cement paste. For age, the compressive strength increases with the increase of age at any ratio.

3.2 Effects of different conditions on setting time

After the above slurry with different proportions was prepared, the initial and final setting time of the slurry with different proportions was measured by vicat apparatus. The test results are as follows:

![Final setting time under different water - cement ratio and fly ash content](image1)

![Initial setting time under different water - cement ratio and fly ash content](image2)

As shown in Fig.1 and Fig.2, the setting time of the slurry is related to the ratio of water to cement.
and the proportion of fly ash in the waste. Under the same ratio of fly ash and water-cement ratio, the initial or final setting time of the slurry increases with the increase of water-cement ratio. Under the same water-cement ratio and different proportion of fly ash, the initial setting time and final setting time of the slurry increased with the increase of fly ash content. This means that the higher the slag content, the more effective it is for early solidification and hardening of the slurry.

3.3 Effects of different conditions on fluidity

Fig.3 shows the slurry fluidity results under the conditions of different water-cement ratios and fly ash ratios:

![Fluidity under different water-cement ratio and fly ash content](image)

Figure.3 Fluidity under different water-cement ratio and fly ash content

As shown in Fig.3, the fluidity of slurry is related to the water-cement ratio and the proportion of fly ash content. Under the condition of the same fly ash content and different water-cement ratio, the fluidity of slurry increases with the increase of water-cement ratio. Under the condition of same water-cement ratio, with the increase of content of fly ash, slag content decreases, the flow of the slurry has obvious increase, this is mainly associated with the composition of fly ash and slag, fly ash in the main material for SiO₂, after mixing with water chemical reactions is not obvious, and the main material for CaO in the slag, water blending generated after the Ca(OH)₂, have to condense.

3.4 Microscopic images under different mixing ratios

Fig.4(a) shows that the image after curing for 28d when the water-cement ratio is 0.8 and the ratio of fly ash to slag is 6:2. Fig.4(b) shows that the image after curing for 28d when the water-cement ratio is 0.8 and the ratio of fly ash to slag is 2:6:

![Curing 28d micro images under different industrial waste content ratios](image)

Figure.4 Curing 28d micro images under different industrial waste content ratios

As shown in figure 4, than under the condition of different proportion of slurry after curing 28d microscopic image has obvious different, than for a 6-2, dosage of fly ash slag can see the gap between the slurry particles is bigger, needle shape AFt content more, because of the late hydration, lead to the content of C-S-H gel is relatively more, so the late strength is relative taller; When the content ratio of fly ash slag is 2:6, it can be seen that the content of acid-like AFt in slurry is significantly lower than that of the former, and the C-S-H gel content is also low, but the content of
flaked Ca(OH)$_2$ is significantly increased, which is also the reason why the slurry has higher strength in the early stage but lower strength in the later stage when the content of slag is high.

4. Conclusion

(1) It is feasible to use industrial wastes such as fly ash and slag as grouting materials. In the appropriate proportion, it has performance parameters that can meet the engineering needs, so as to meet the engineering needs, as well as waste utilization, environmental protection and cost reduction.

(2) The two kinds of industrial wastes, fly ash and slag, have different properties. The grouting materials with higher slag content have higher compressive strength in the early stage and lower compressive strength in the later stage. However, the early compressive strength of the grouting material with high fly ash content was lower, but the later strength increased significantly, and its fluidity was better than that of the grouting material with high slag content.

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