Experimental Study on the Strength of Fly Ash Geopolymer with Alkali Activator Modulus

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Abstract. The variation of strength of fly ash geopolymer under different alkali activator modulus is studied. In this paper, three samples with modulus of alkali initiator 1.0, 2.0, 3.0 were prepared by laboratory test, and the unconfined compressive strength, SEM scanning and XRD analysis were conducted. Results show that the strength of the fly ash geopolymer negative correlation with alkali excitation agent module, with higher modulus alkali excitation agent, the strength of the polymer decreased obviously. From the micro perspective, the lower modulus of the sample of the microstructure appear more dense, gelling material produce more obvious at the same time. From the part of XRD, different modulus of the sample composition are same basically.

1. Introduction
Thermal power in the energy structure of the whole world still irreplaceable status in a short time, which also brought a lot of environmental problems, the fly ash as the main industrial production waste of power plants, due to its high yield and utilization ratio is very low, occupy a large amount of land, and caused the clear air and land pollution, therefore, the rational use of fly ash for the environment and has obvious economic benefit.

Fly ash is a kind of vitreous particle material, its main components are SiO₂ and Al₂O₃, etc., these components have chemical activity, can be activated by alkaline substances, to form a solid with cementing properties, has a fairly high strength, the generated such substances are called geopolymers. At present, this kind of material has been extensively studied. Some scholars have studied the effect of raw materials and additives on fly ash polymers [1-4]. The system performance of geopolymers [5-6] and its early performance [7-8] have also been studied in depth. Many scholars have applied fly ash polymers to strengthen soft soil foundation [9-10]. In general, fly ash can be used as a good construction material in practice.

2. Experiment
2.1. Experiment materials
The fly ash used in this test was purchased from a power plant in henan province. It is a first-class fly ash. Its basic physical properties and ingredients are shown in table 1 and table 2 respectively.

| Project | Specific surface area /m²·kg⁻¹ | Stacking density /g·cm⁻³ | Water requirement /% | Loss on ignition /% |
|---------|---------------------------------|--------------------------|---------------------|---------------------|
| result  | 431                             | 0.8                      | 92.1                | 2.53                |

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Table 2. Fly ash composition list

| Material   | SiO₂ | Al₂O₃ | Fe₂O₃ | CaO | K₂O | MgO | Na₂O | Loss |
|------------|------|-------|-------|-----|-----|-----|------|------|
| Fly ash    | 56.1 | 27.1  | 4.99  | 4.16| 2.94| 1.29| 0.57 | 2.53 |

2.2. Experiment scheme
The modulus of alkali initiator sodium silicate can be adjusted by using NaOH. The design scheme of this test is shown in Table 3.

| formula                | sodium silicate content/% | Water content/% | Sodium silicate modules | Curing age /d |
|------------------------|---------------------------|-----------------|-------------------------|---------------|
| Fly ash+sodium silicate+NaOH+water | 20                         | 20              | 1.0                     | 2.0           | 3.0       | 3    |

2.3. Experiment method
According to design good weighing material ratio, stir well, pour into 70.7 mm × 70.7 mm × 70.7 mm standard mold for molding, each module made three sets of sample, calculate the average, stay three days later to take out the sample on the unconfined compressive strength test (test instrument (see figure 1), and from the middle part of the crushed sample for SEM and XRD test (see figure 2) testing equipment.

3. Result and discussion

3.1. Fly ash ground polymer strength of different modulus
After curing for three days, unconfined compression test was carried out on three samples with excitation agent modulus, and the test results were as follows:

| Sample Result module | 1.0 | 2.0 | 3.0 |
|----------------------|-----|-----|-----|
| Sample 1             | 6.811| 1.258| 1.394|
| Sample 2             | 7.327| 1.324| 1.476|
| Sample 3             | 6.893| 1.319| 0.964|
| Average              | 7.010| 1.300| 1.278|

From the above test results, the fly ash geopolymer compressive strength and modulus of alkaline
exciting agent exist obvious relations, in particular, when the module is 1.0, the fly ash to polymer can show high compressive strength, the modulus increased from 1.0 to 2.0, and the compressive strength will be intense by 81.46%, and when the modulus of continue to reduce to 3.0 to polymer compressive strength of fly ash in terms of the modulus of 2.0, while also continue to reduce, but only by 1.7%, little change. Therefore, it can be proved that the modulus of alkali activator has a great influence on the strength of fly ash ground polymers, and there should be an optimal value point to maximize the strength of fly ash ground polymers.

3.2. Microstructure of fly ash ground polymers with different modulus

After pressing the fly ash ground polymers with different modules, samples were sampled for SEM test. The obtained images are shown in figure. 3 and figure. 4, which are pictures with a magnification of 500 times. Under this multiple, the differences of fly ash ground polymers with different modules can be clearly seen.

Figure. 3 is the image of modulus 3.0 and figure. 4 is the image of modulus 1.0. It can be seen that the samples with modulus 3.0 have more discrete microstructure, with great differences in particle size and uneven distribution, resulting in obvious pores. However, in comparison, the sample with the modulus of 1.0 has more uniform particle size and little difference in particle size. The distribution is more regular, and the pore structure is significantly reduced. At the same time, it can be seen that there are obvious cementing substances attached between the particles.

3.3. XRD patterns of fly ash polymers with different modulus

After the XRD test of fly ash ground polymer samples with modulus 1.0 and 3.0, the results are as follows:
the strength difference of samples with different modulus is more likely due to the influence of modulus on the physical properties inside the system.

4. Conclusion

(1) The strength of the fly ash geopolymer is affected by the modulus of the alkali excitation agent, when low modulus, polymer has high strength, and as the modulus increase gradually, to the strength of the polymer decreases, but the process is not linear, modulus is a significant point, when the module to achieve this, suddenly to gather strength is reduced, and then with the module we will continue to increase, to gather strength reduction of no longer apparent.

(2) Different modulus of fly ash geopolymer under the condition of different intensity, the reason for the inside of a system under the conditions of different modulus of the physical properties of the differences, and different modulus of alkaline exciting agent shows differences in nature, rather than because of the different chemical changes in different modulus, in the process of the whole test, under different modulus in the polymer system did not generate any new material.

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