Study on the Effect of Mineral Powder and Fly Ash on Cement Hydration Heat

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Abstract. In this paper, the hydration heat and hydration temperature-time curves of different proportions of cement, fly ash, mineral power, and fly ash and mineral power at different ages were studied. The results showed that compared with cement alone, fly ash and the heat of hydration of cement at different ages had been reduced, and the maximum temperature had been reduced to varying degrees. The maximum temperature time had been advanced compared to cement, and the reduction of the hydration heat of cement by pulverized coal was higher than that of pulverized coal. Ash reduced the heat of cement hydration. When cement was replaced by fly ash and mineral power in different proportions, the heat of hydration was also reduced, but the reduction was disproportionate. As the blending ratio increased, the degree of hydration of the cement decreased and the maximum temperature decreased. The reduction of hydration heat of fly ash was better than the end of the initial period, but the reduction of heat of hydration by mineral powder was not very obvious, but it can slow down the heat release rate of hydration heat significantly.

1. Introduction
With the development of modern science, the application of concrete has become more and more extensive. Cement is one of the most used materials in concrete. Cement participates in hydration during the process of participation, and the cement releases a large amount of heat of hydration during the process of hardening. Corresponding temperature stress is generated during the process of releasing the heat of hydration, and the appearance of temperature stress is the occurrence of cracks in the concrete. An important reason for the impact on concrete is more significant. Therefore, many experts and scholars have studied the heat of hydration [1-2]. Fly ash is the main industrial waste discharged from industrial power plants. It is a mixed material with active pozzolanic material. The morphological effect, micro-aggregate effect and pozzolanic effect of fly ash have been fully exerted, and it can act as a solid water reducing agent. In the concrete application process, it has become an indispensable blending material. Mineral powder is also a kind of industrial waste slag, the main component is calcium silicate, and the main raw materials are produced in southwestern provinces such as Yunnan, Guizhou and Sichuan. If the mineral powder can be used reasonably, the mineral powder can be turned into treasure, and the environment can be optimized and protected. In the process of concrete construction, some measures will be adopted to achieve the purpose of controlling the temperature of concrete. For example, mineral powder and fly ash can be used to replace part of the cement to meet various performance
requirements of concrete and reduce the internal temperature of concrete. Therefore, many scholars have studied the heat of hydration of cement mixed with fly ash and mineral powder [3-6].

In this paper, the heat of hydration of cement, fly ash and mineral powder, the heat of hydration mixed with different proportions of fly ash and mineral powder and the hydration temperature-time curve were studied to investigate fly ash and the influence of mineral powder on the heat of hydration.

2. Experiment part

2.1. The main raw materials

The cement used in the test was MinFu cement produced by Fujian Yongding MinFu Materials Co., Ltd., PO 42.5 ordinary Portland cement, and fly ash was produced by Fujian Yong’ an Ruixiang Fly Ash Technology Co., Ltd. The powder is from S95 mineral powder, from Fujian Sanbao Iron and Steel Co., Ltd. The chemical composition data of cement, fly ash and mineral powder were shown in table 1, and the particle size distribution data was shown in table 2. The test water came from tap water in the laboratory. The raw materials for testing the heat of hydration and the test water were kept constant at 20°C for 24 hours.

| Sample name | Fe₂O₃ (%) | Al₂O₃ (%) | SiO₂ (%) | CaO (%) | MgO (%) | SO₃ (%) | Na₂O (%) | K₂O (%) | Loss on ignition (%) |
|-------------|-----------|-----------|----------|---------|---------|---------|----------|---------|---------------------|
| cement      | 5.59      | 8.13      | 25.54    | 52.27   | 1.36    | 0.82    | 0.13     | 0.60    | 1.75                |
| Mineral power | 2.42     | 12.22     | 16.76    | 36.46   | 1.21    | 1.79    | 0.24     | 1.30    | 1.23                |
| Fly ash     | 3.80      | 15.14     | 78.61    | 2.98    | 0.95    | 0.19    | 0.22     | 0.29    | 0.86                |

Table 1 showed the test results of the chemical composition of cement, mineral powder and fly ash. According to the data, the chemical composition of cement meets the relevant requirements of GB175-2007 for ordinary silicate; The chemical composition data of mineral powder meets the requirements of DL/T5387-2007; the chemical composition data of fly ash conforms to DL/T5055-2007.

| Sample name | X50 (μm) | <3μm (%) | 3~32μm (%) | 32~65μm (%) | >65μm (%) | >80μm (%) |
|-------------|----------|----------|------------|-------------|-----------|----------|
| cement      | 15.984   | 17.297   | 65.030     | 17.036      | 0.637     | 0        |
| Mineral power | 11.370 | 22.878   | 71.272     | 5.850       | 0         | 0        |
| Fly ash     | 13.310   | 25.798   | 52.594     | 18.033      | 3.575     | 1.726    |

Table 2 shows the particle size distribution results of cement, mineral powder and fly ash. The data shows that the X50 of cement is 15.984μm, the X50 of mineral powder is 11.370μm, and the X50 of fly ash is 13.310μm. The particles of cement are relatively relatively The main effect of 3~32μm particles, cement is 65.030%, mineral powder is 71.272%, fly ash is 52.594%, and the proportion of mineral powder is larger.

2.2. Performance test method

The test was carried out using the direct method (substitution method) specified in GB/T 12959-2008. The water used in the test was laboratory tap water. The water, cement, mineral powder and fly ash used in the test were all placed under the temperature conditions required by the test for 24 hours. Experiments were carried out with different mixing ratios of cement, fly ash and mineral powder, and the heat of hydration of cement at 1d, 2d, 3d, 4d, 5d, 6d and 7d under each mixing ratio was measured.
3. Results and discussion

3.1. The heat of hydration of individual cement, mineral powder and fly ash

First, the heat of hydration of cement, powder and fly ash was investigated. The total was 400 g. The heat of hydration of different materials at different ages was shown in Figure 1, and the hydration temperature-time curve at different times is shown in Figure 2. It can be seen that under the same test conditions and at the same age, the heat of hydration of cement, mineral powder and fly ash are different. The heat of hydration of cement is the largest, while that of fly ash is the smallest. The heat of hydration of powder and fly ash are relatively close at the same age. There is little difference in the onset temperature of the heat of hydration between the three, but the hydration temperature-time curve of the three is quite different. As shown in Figure 2, the cement reaches the maximum temperature at about 24h, and the temperature gradually decreases after 24h, and the temperature gradually decreases at 120h. Tend to equilibrium, while the maximum temperature of slag and fly ash appears at the initial temperature, then slowly decreases, and tends to balance at 48h. The temperature difference of cement is 6.08 °C, and the maximum temperature time is 11.5h. The maximum temperature and time of coal ash and mineral powder both appeared in 0.5h. It can be seen that the heat of mineral powder and fly ash is almost completely released within 48h, and the heat of cement is released within 120h, which is released quickly in the early stage.

3.2. Heat of Hydration of Single Blended Fly Ash

For single-mixed fly ash with different proportions of hydration heat and different time hydration temperature-time curve is shown in Figure 3, different time hydration temperature-time curve is shown in Figure 4. It can be seen Figure 3 that after a certain amount of fly ash is mixed, the heat of hydration decreases. With the increase of the amount of fly ash, the heat of hydration of each age decreases. The more ash is incorporated, the more the heat of hydration decreases. It may be due to the unstable activity of fly ash. After the hydration reaction occurs, hydration products will adhere to the surface of fly ash, which will inhibit the hydration reaction of cement and reduce the heat of hydration. It can also be seen from the hydration temperature-time curve of fly ash mixed with different proportions that with the increase in the amount of fly ash, the hydration temperature-time curve and the hydration heat change curve are the same. The increase of ash content will lower its maximum hydration temperature.
3.3. Blended with fly ash and mineral powder hydration heat

The heat of hydration mixed with different proportions of fly ash and mineral powder is investigated. The data of the heat of hydration with different proportions and different ages was shown in Figure 5. The hydration temperature -time curve was shown in Figure 6. It can be seen that when fly ash and slag were mixed, the heat of hydration decreases more. When the amount of fly ash and mineral powder blended in different proportions, the amount of reduction was different. When the amount of mineral powder blended was more than the amount of fly ash blended, the heat of hydration was reduced more, and the water changed trend of temperature-time change was consistent with its change trend, but the hydration temperature was relatively low when the amount of mixed mineral powder was large.

4. Conclusion

Compared with cement alone, fly ash and mineral powder have reduced the heat of hydration of cement at different ages, and the maximum temperature is also reduced to varying degrees. The maximum temperature time is earlier than that of cement. The degree of reduction of the heat of hydration is higher than the degree of reduction of the heat of hydration of cement by fly ash. When different proportions of fly ash and mineral powder replace cement, the heat of hydration is also reduced, but the reduction is disproportionately. As the mixing ratio increases, the reduction in cement hydration increases and the maximum temperature also decreases. Fly ash reduces the heat of hydration at the initial stage better
than at the end, while the reduction of the heat of hydration with slag powder is not very obvious, but it can significantly slow down the heat release rate of hydration.

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