The effect of fly ash on the mechanical properties of cinder lightweight aggregate concrete

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Abstract. The volcanic cinder is a kind of porous rock with good performance and is formed by the cooling of the volcanic eruption. This paper studies the effect of fly ash on the mechanical properties of cinder lightweight aggregate concrete. Results show the mechanical properties of cinder lightweight aggregate concrete is significantly improved with fly ash, and it has a maximum strength value when the dosage is 35%; the early strength of lightweight aggregate concrete is greatly improved, when we extend the grinding time of fly ash, decrease the particle size and increase the activity.

1. Introduction

The volcanic cinder is a kind of porous rock which is formed by the cooling of the volcanic eruption, and the porous system is caused by gas expansion. Cinder is a kind of good natural lightweight aggregate. The inner pore for volcanic cinder is like honeycomb. Moreover, the pores are tough, light and pure, mostly used for high quality products. The new wall products will have a broad application prospects which produced by cinder, this product does not only have the advantages of light weight, heat insulation, good sound insulation, simple process and low price, but also meets the demands of building energy saving and reducing structure weight⁴³.

2. Materials

(1) Cement: adopt the cement of ordinary Portland cement, and it has the strength grade of 42.5.

(2) The chemical composition of fly ash is shown in Table 1. The microstructure is shown in Fig.1.

| The ignition loss | SiO₂ | Al₂O₃+TiO₂ | Fe₂O₃ | CaO | MgO |
|------------------|------|------------|-------|-----|-----|
| 2.86             | 62.52| 22.89      | 4.00  | 0.67| 1.15|

(3) The cinder. The volcanic cinder is produced in Jingyu County of Jilin Province, the physical properties are shown in Table 2. The chemical composition is shown in Table 3, and the micro structure is shown in Fig.2.

| Max size | volume weight (kg/m³) | Void fraction (%) | Porosity (%) | Water absorption (%) | Softening coefficient |
|----------|------------------------|-------------------|--------------|----------------------|----------------------|
| 15       | 670                    | 52.2              | 49.2         | 13                   | 1.0                  |
3. The experimental results and discussion

3.1. The effect of fly ash replacement on the mechanical properties
From Fig.5, when we increased the amount of fly ash, it had a maximum strength value when the dosage was 35%; due to the pozzolanic activity of fly ash, and the active ingredient had an Alkali reaction with the Ca(OH)$_2$ which came from hydration of cement, the hydration of calcium, the calcium silicate hydrated calcium aluminate and the hydrated silicon aluminum products were produced in this process, and the bonding ability of the matrix and the structural compactness of the hydration products were improved. Therefore, the strength of this concrete is improved.

3.2. The fly ash particle size influence of grinding time change

The fly ash is composed of vitreous mineral, and its surface is hard and dense, and we can improve the activity of fly ash by grinding, destroy the coating of the vitreous body or crush the particles. This experiment through analyzing different grinding time for particle size of fly ash, the experimental results were shown in Table 4 and Fig.4, and microscopic state was shown in Fig.3.

From Fig.4, the activity of fly ash particles was increased with the grinding time increased and the average particle size decreased. The early strength and the fluidity of cement were improved.

### Table 3. The chemical composition of cinder

| SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | CaO  | MgO  | SO$_3$ | K$_2$O | Na$_2$O |
|---------|-------------|-------------|------|------|--------|--------|--------|
| 49.11   | 17.02       | 10.04       | 6.59 | 5.40 | 0.03   | 2.64   | 4.26   |

### Table 4. The influence on the particle size of fly ash with grinding time

| Grinding time (min) | Max size (µm) | Average size (µm) | Surface area/volume (cm$^2$/cm$^3$) |
|---------------------|---------------|-------------------|-------------------------------------|
| 0                   | 58            | 22.42             | 7154                                |
| 20                  | 42            | 14.15             | 11701                               |
| 30                  | 44            | 11.77             | 13565                               |
| 40                  | 36            | 9.72              | 16167                               |
| 50                  | 44            | 8.69              | 17645                               |
| 60                  | 24            | 8.16              | 18257                               |

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3.3. The influence of different grinding time of fly ash

The fly ash was grinding with 0min, 30min, 40min, 50min, 60min respectively, and it was added 35%, and we had studied the influence of the different grinding time of fly ash on the mechanical properties of lightweight aggregate concrete, the experimental results was shown in Fig.6, and the interface of cinder aggregate and hydration products scanning electron microscopic diagram was shown in Fig.7.

From Fig.6, the compressive strength of cinder lightweight aggregate concrete was increased with the grinding time increased of fly ash, and the strength reaches the maximum value, when the fly ash was grinding 40min. The main reason: The crystal structure was destroyed after grinding of fly ash particle surface, and the chemical bond was broken in the chemical bond. At this time, the crystal surface was in a metastable state, which is prone to hydration reaction, and the activity of fly ash was increased; on the other hand, the particle size became smaller after the fly ash was grinding, the specific surface area was increased, the area of the unit mass of fly ash and the hydration reaction was increased, and more hydration products can be generated. It was conducive to the improvement of strength. At the same time, the micro aggregate effect of fly ash was increased, and it makes the structure more compact. And a large number of loose porous carbon particle structure were exposed when we had a too long grinding time, and the water demanded of hydration reaction was increased, and the strength was decreased at the same time. From Fig.7, the hydration products are more abundant in the slag aggregate, and the interfacial transition zone is continuous, which shows that the slag and cement stone matrix can form a solid interface effect. The cinder was fully wrapped by hydration products, and the interface transition zone was continuous, this shows a solid interface could be formed between the cinder and cement stone.
Figure 7. The SEM diagram of the interface of cinder aggregate and hydration products

4. Conclusion
The fly ash had a great influence on the mechanical properties of cinder lightweight aggregate concrete, and with the fly ash content increased, the compressive strength of cinder lightweight aggregate concrete had been improved obviously, and it had a maximum strength value when the dosage was 35%. The activity was increased and the average particle size was decreased of fly ash with the grinding time increased. All of these had obviously improved the fluidity and the early strength of lightweight aggregate concrete.

References
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