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# Effect of ultra-fine composite Mineral Admixtures on the Mechanical Properties and Slump of Concrete
# Influence of quartz sand on the properties of foam concrete

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## ABSTRACT

With the technology of the Mineral Admixtures' application in Cement-based materials becoming mature, the ultra-fine of mineral admixtures has also become a trend. After ultra-fine, the hydration activity of the mineral admixtures is greatly improved, while increasing the degree of structural compactness of Cement-based materials, improving the workability of Cement-based materials. The mineral admixtures applying to concrete materials after ultra-fine, which has a certain improvement effect on the performance of concrete. In this paper, the effect of ultra-fine mineral admixture on the workability of dry hard concrete and the high-performance concrete was investigated. The proportion of ultra-fine composite mineral admixture replacing cement was 0, 20% and 30% respectively, and the workability of concrete was characterized by compressive strength, flexural strength and slump. Meanwhile, the effect of ultra-fine mineral admixture on the hydration products of concrete was characterized by Quantitative XRD. According to the experimental results, the ultra-fine mineral admixture can significantly increase the mechanical strength of concrete, reduce the water requirement of concrete and improve the flowability of concrete materials. The clinker content in the hydration products was significantly consumed, accelerating the hydration of $C_2S$ and $C_3S$ in the cement.

## 1. INTRODUCTION

Today, Concrete materials are one of the most widely used materials in the world. With the gradual acceleration of the modernization process in Our country, the construction are tend to huger, the application environment is more complex, the demand and the requirements for work performance of concrete have also risen to a new level [1]. The use of ultra-fine mineral admixtures as a partial replacement for cement not only reduces the amount of cement used, which in turn reduces the pollution caused by the cement production process, but also reduces construction costs. After the mineral admixture ultra-fine, it can better play the micro-filling effect, morphological effect, specific gravity effect, dispersion effect and volcanic ash effect of mineral admixture, not only play the role of plasticity and water reduction, but also improve the strength of the interface between cement stone and aggregate in concrete, reduce porosity and make pore refinement, generating more C-S-H gel, improve the mechanical properties and durability of concrete [2].

There have been many studies on the application of the ultra-fine mineral admixtures to cement-based materials: NV Tuan et al. prepared ultra-high performance concrete with 28d compressive strength of 180MPa and 91d compressive strength of 210 MPa using ultra-fine rice husk ash as a substitute for cement [3]; Wang Xiaodong et al. conducted a study on the effects of compounding fly ash and ultra-fine slag on the mechanical and durability properties of high performance concrete The study concluded that the tensile properties of high performance concrete were mostly improved when compounded with 10% fly ash and 10% ultra-fine slag [4]; Liu Yaolin et al. explored the effect of ultra-fine slag on the performance of silicate cement, and the flow of cement-based materials decreased linearly with the increase of ultra-fine powder in the range of 5% to 20%, while the incorporation of ultra-fine powder promoted the hydration of cement-based materials and increased the late strength [5]; Song Yuhua et al. Optimized the design of high performance concrete mix ratio of double-doped ultra-fine fly ash and slag with the help of indoor orthogonal tests, on the premise that the total amount of ultra-fine fly ash and slag remains unchanged, the flexural strength of the specimens achieves to peak when the ratio of ultra-fine fly ash to slag is 1:1, and the mass loss rate of the specimens is minimized with the best effect of freeze-thaw cycle resistance [6].

At present, there exits many studies on the performance of single ultra-fine mineral admixture on cement-based materials, but less description of the performance of composite ultra-fine mineral admixture on cement-based materials. In this paper, we use ultra-fine composite mineral admixtures to replace 0, 20% and 30% of cement to prepare dry hard concrete and high-performance concrete respectively, to investigate the effect of composite mineral admixtures on the compressive and flexural strength and slump of concrete. the effect of ultra-fine composite mineral admixtures on hydration products will also be introduced using quantitative XRD.

## 2.RAW MATERIALS AND EXPERIMENTAL METHOD

### 2.1 Materials

Ordinary Portland cement, ultra-fine composite mineral admixture, stone, river sand and Polycarboxylate Superplasticizer.

The component analysis of the ultra-fine mineral admixture is shown in Table 1.

**Table 1.** Chemical properties of ultra-fine mineral admixture

| CaO (%) | $SiO_2$ (%) | $Al_2O_3$ (%) | MgO (%) | $P_2O_5$ (%) | $K_2O$ (%) | LOI (%) |
|---|---|---|---|---|---|---|
| 21.37 | 27.52 | 20.18 | 3.51 | 0.15 | 0.50 | 0.50 |

2.2 Mix proportions

Ultra-fine mineral admixtures replace cement in dry hard concrete and high performance concrete in amounts of 0, 20% and 30% respectively.

**Table 2.** Mix proportions of concrete

| Mix number | Cement ($kg/m^3$) | ultra-fine mineral admixture ($kg/m^3$) | Stone ($kg/m^3$) | River sand ($kg/m^3$) | *w/b* |
|---|---|---|---|---|---|
| **1** | 330 | 0 | 1490 | 669.9 | 0.34 |
| **2** | 264 | 66(20%) | 1490 | 669.9 | 0.34 |
| **3** | 231 | 99(30%) | 1490 | 669.9 | 0.34 |

**Table 3.** Mix proportions of high performance concrete

| Mix number | ultra-fine mineral admixture (%) | Cement (g) | River sand (g) | Stone 5-10 Mm (g) | Stone 10-20 mm (g) | Superplasticizer (g) | w/b |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 480 | 780 | 430 | 647 | 5.76 | 0.34 |
| 2 | 20% | 384 | 780 | 430 | 647 | 5.76 | 0.34 |
| 3 | 30% | 336 | 780 | 430 | 647 | 5.76 | 0.34 |
| 4 | 30% | 315 | 780 | 430 | 677 | 5.76 | 0.34 |

### 2.3 Specimen preparation

Mixing and blending of the dry materials is in accordance with the standard JGJ 55 201J. It was cured under standard curing conditions for 24h at a temperature of 20±5°C. The specimens are then demolded and numbered. Immediately placed in a standard curing room at a temperature of 20±2°C and a relative humidity of 95%. For all tests, 3 specimens for every mix proportion were prepared, and the average value of 3 specimens was reported.

### 2.4 Compressive strength

According to the standard GB/T 50081 2002, the loading rate is 0.8MPa/s and the specimen size is 100*100*100mm.

### 2.5 Flexural strength

The measurement of the flexural is In accordance with the standard GB/T 50081 2002, the loading rate is 0.08 MPa/s and the specimen size is 100*100*400mm.

### 2.6 Fluidity

In accordance with the standard GB/50080-2002-T, concrete mix slump and slump expansion values are measured to an accuracy of 1mm.

### 2.7 Quantitative xrd analyzation

The prepared concrete specimens are cured to standard ages, grounding to pass through a two hundred mesh sieve and calibrated for the hydration product components using the internal standard method.

## 3 EXPERIMENTAL RESULTS AND DISCUSSION

### 3.1 Compressive and flexural strength

Figure 1 shows the 3d, 7d and 28d compressive strengths of dry hard concrete respectively. It can be seen from that the improvement of the 3d strength of dry hard concrete was weaker than late period when the ultra-fine mineral admixture was incorporated; when the ultra-fine mineral admixture was incorporated to 30%, the strength of the concrete showed some decreases. When the ultra-fine mineral admixture was incorporated to 20%, the 28d compressive strength reached 74.3MPa, which is 15.6% higher compared to the dry hard concrete with pure cement. Figure 2 shows the 7d and 28d flexural strengths of the dry hard concrete. In contrast to the effect of the ultra-fine mineral admixture on the compressive strength, at 30%, the ultra-fine mineral admixture has a significant increase in the 28d flexural strength of 6.71 MPa, an increase of 6% compared to the dry hard concrete without mineral admixture.

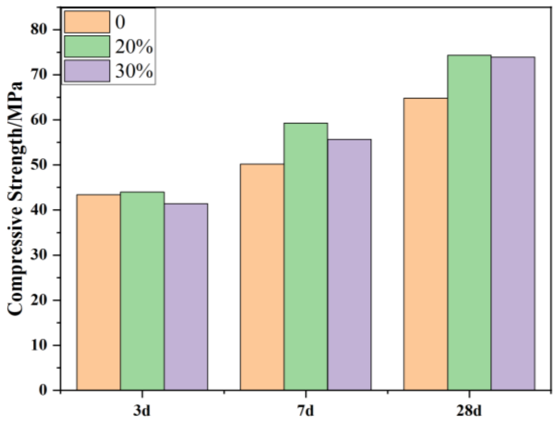


**Figure 1.** Compressive Strength of hard concrete.

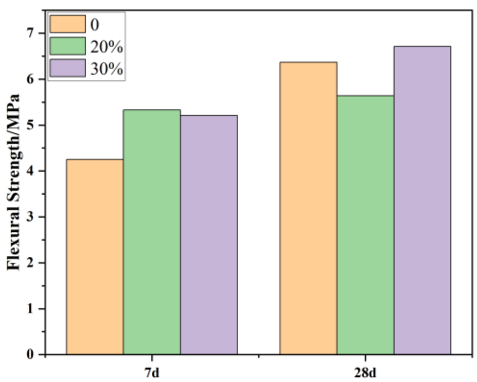


**Figure 2.** Flexural Strength of hard concrete.

Figure 3 shows the 3d, 7d, 14d and 28d compressive strength of high-performance concrete. For sample 4, 30% of cement was replaced using ultra-fine mineral admixtures with a reduced amount of binding material, with the aim of investigating the effect of ultra-fine mineral admixtures on the workability of concrete with reduced binding material. Similar to the effect of ultra-fine mineral admixtures on the compressive strength of dry hard concrete, the early strengths of high performance concrete showed varying degrees of reduction following the incorporation of ultra-fine mineral admixtures, but the later strengths all increased. At the same time, sample 4 showed little loss of strength compared to sample 3 at a reduced amount of binding material. Sample 4, with a binding material weight of 450 and a 30% admixture of ultra-fine powder, showed a 5% increase in 7d strength compared to sample 1 with a binding material weight of 480 and no admixture of ultra-fine powder. Therefore, cost reductions can be made by using ultrafine mineral admixtures .

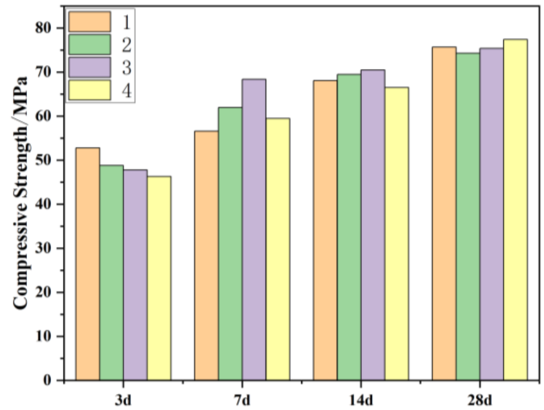


**Figure 3.** Compressive strength of high performance concrete.

## 3.2 Fluidity

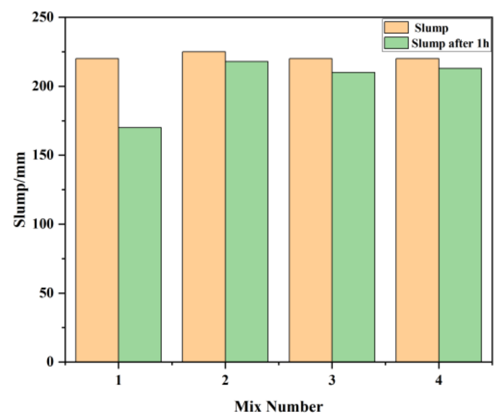


**Figure 4.** The slump and the slump after 1h of High performance concrete.

Figure 4 shows the slump and the loss of slump after 1h of different samples with different content of mineral admixtures. The 1h loss of slump of control group was 22.7%. After the ultra-fine mineral admixture was mixed, the loss of slump of the concrete was reduced to 3%-4.5%. It is also evident from the graph that the inclusion of ultra-fine mineral admixtures significantly reduces the concrete's slump loss. This is because, under the effect of micro-grading, the ultra-fine powder improves the slump and water retention, reduces the viscosity of the concrete, makes the concrete’s pouring state remain basically the same, thus improves the construction quality of the concrete.

## 3.3 Quantitative XRD analyzation

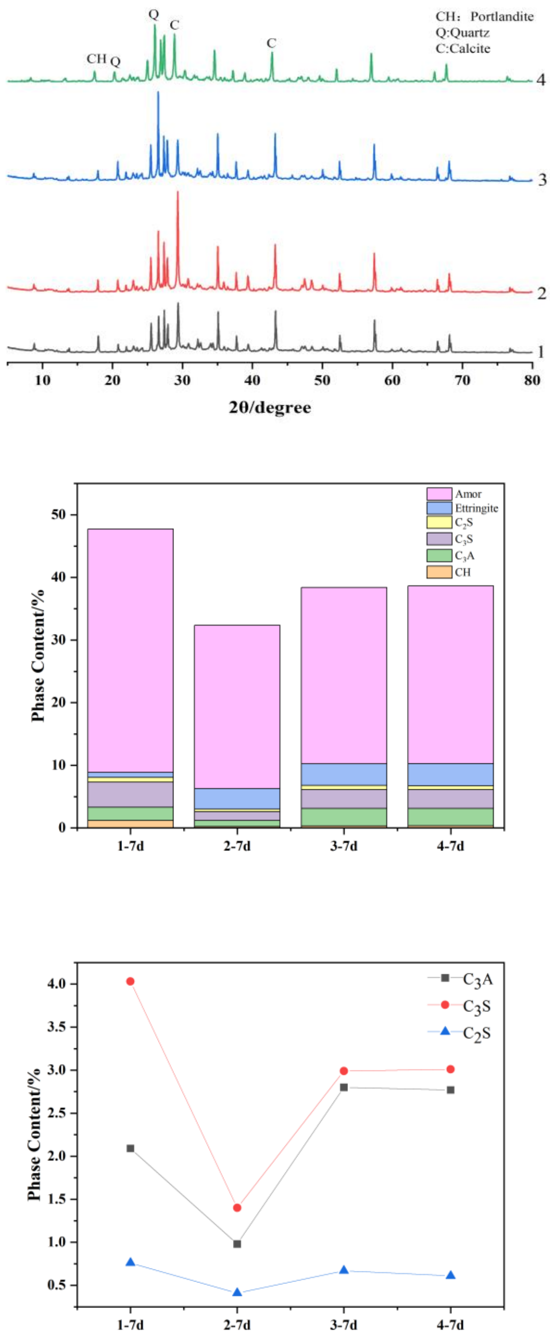


**Figure 5.** The Quantitative XRD patterns of hydration product of 7d.

Figures 5 analyze the 7d hydration products of the high-performance concrete. $Ca(OH)_2$ crystals are almost disappeared and the samples are partly carbonated in 7d hydration products, As the amount of ultra-fine mineral admixture increased, the intensity of the diffraction peak of reactive silica also tended to increase significantly. This is because the active silica and alumina in the ultra-fine mineral admixture react with $Ca(OH)_2$ produced by cement hydration to produce C-S-H/C-A-S-H gel, which is conducive to improving the strength of concrete. At the same time, the ultra-fine powder particles are dispersed in the concrete and fill in the gaps created by the hydration of the cement, further improving the densities of the concrete and also contributing to the increase in concrete strength. Also, the results of the quantitative XRD analysis of the cement clinker content indicate that the incorporation of the ultra-fine mineral admixture accelerates the hydration of calcium aluminate in the early stages of hydration and calcium silicate in the later stages.

## 4. CONCLUSION

According to the above experimental data, the following conclusions can be obtained.

(1) ultra-fine composite mineral admixture can significantly improve the strength and the loss of slumps of concrete, and the improvement of strength in the later stage is more significant.

(2) The ultra-fine mineral admixture can better play the micro-aggregate effect and volcanic ash effect, accelerating the hydration of calcium aluminate in the early stage of hydration and calcium silicate in the late stage of hydration.

## REFERENCES

1. Yang L.J. 2005. Study on the application of slag ultrafine powder in cement.
2. Wang C. Pu X.C. 2001. Plasticization and water reduction of fresh concrete by ultra-fine mineral admixtures. Mechanism analysis. Concrete, 8: 51-54.
3. Tuan N.V., Ye G., Breugel K.V., et al. 2011. The study of using rice husk ash to produce ultra-high performance concrete. Construction & Building Materials, 25(4): 2030-2035.
4. Wang X.D. 2022. Compounding of fly ash and ultra-fine slag study on the influence of high performance concrete on mechanical and durability performance. Contemporary Chemical Industry, 50(1): 35-28.
5. Liu Y.L., et al. 2016. Study on the effect of ultra-fine slag micronized powder on the performance of silicate cement. Cement Engineering, 6: 7-9.
6. Song Y.H., et al. 2022. High-performance concrete with double-doped superfine fly ash and slag Optimisation of mix ratio design. Contemporary Chemical Industry, 51(1): 22-25.