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# Review of Research on Volume Shrinkage Regulation Mechanism of Ultra-high Performance Concrete

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**Abstract:** Ultra-high performance concrete (UHPC) is a cement-based composite building material with excellent durability and mechanical properties, but its autogenous shrinkage and drying shrinkage phenomenon have become a common problem in practical engineering. In order to solve this practical problem, new mineral admixtures and admixtures are usually added to UHPC, and the shrinkage of UHPC is effectively improved.

**Keywords:** Autogenous shrinkage; drying shrinkage; mineral admixture; admixture.

## 1. Research Status at Home and Abroad :

The shrinkage of ultra-high performance concrete ( UHPC ) refers to the phenomenon of volume reduction caused by the hydration reaction of internal cementitious materials or the change of internal temperature and humidity caused by the change of external environment in the process of setting and hardening of concrete. However, the volume deformation of

UHPC can be effectively reduced by adding some new mineral admixtures into the original mix ratio to replace cement and exert dilution effect.

### 1.1. Research status of the effect of mineral admixtures on the volume shrinkage of cement-based materials at home and abroad

Li Yaqiang[1] discussed the effect of carbon nanotubes ( CNTs ) on the autogenous shrinkage of cement paste. The addition amount of CNTs was 0.025 %, 0.05 %, 0.075 %, 0.1 % and 0.125 % of cement mass. The results show that the self-shrinkage rate of cement paste with 0.05 % CNTs is the lowest.

Syed Hissan[2] used 10 %, 15 % and 20 % rice husk ash to replace cement, which can give full play to its volcanic ash potential. The study found that with the increase of rice husk ash replacement rate, the self-shrinkage rate and self-shrinkage of HPC decreased, but after 7 days, 20 % rice husk ash had little effect on the self-shrinkage of HPC, and its self-shrinkage value was slightly lower than 15 %.

Ma[3] found that with the increase of fly ash content, the total porosity of concrete decreases, and the proportion of small capillary pore diameter decreases, so the autogenous shrinkage of concrete decreases.

Zhang[4]used steel slag to replace part of cement, and found that with the increase of steel slag content, the autogenous shrinkage of UHPC decreased significantly.

Chen Mei[5]studied the effect of granite powder on the autogenous shrinkage of mortar. The results showed that with the increase of granite powder content, the autogenous shrinkage of mortar increased first and then decreased. The main reason is that granite powder can change the type and quantity of hydration products of mortar, and then affect the trend of autogenous shrinkage.

According to Wu Xian[6], rice husk ash, due to its special pore structure, can play a role of water storage in the process of concrete autogenous shrinkage, thus further inhibiting autogenous shrinkage; the pore structure is refined and the number of capillary pores is increased by the glass micropowder, which leads to the aggravation of self-drying.

Han Hongwei[7]studied the effect of fly ash content on early autogenous shrinkage, plastic shrinkage cracking and long-term drying shrinkage of low water-binder ratio concrete. The test results show that the use of fly ash effectively improves the volume stability of low water-binder ratio concrete. When the content of fly ash reaches 30 %, the volume stability of concrete is greatly improved.

### 1.2. Research status at home and abroad on the effect of admixtures on the volume shrinkage of cement-based materials

Many scholars have done a lot of research on the effect of admixtures on the shrinkage performance of concrete, but different researchers have different conclusions. Abolfathi Mehrnosh[8]added 1.5 % and 3 % shrinkage reducing agent ( SRA ) to cement-based materials. The results showed that compared with the standard group, the volume deformation of cement-based materials decreased by 28 % and 53 %, respectively. This shows that the shrinkage reducing agent has a good inhibitory effect on the shrinkage of concrete.

Estensen K A[9] used different dosage of shrinkage reducing agent to discuss its influence on volume deformation. The results show that the more the dosage, the better the shrinkage reduction effect of concrete.

In order to reduce the risk of cracking of high strength mortar, Yang Guo[10] added calcium-based expansive agent and super absorbent polymer ( SAP ) to concrete. Although both of them can increase the early expansion deformation of concrete, there is still a risk of cracking in the later stage.

Zhang Zhanqiang[11] added 3 %, 6 % and 9 % magnesium oxide expansive agent to UHPC. The results showed that the autogenous shrinkage of UHPC matrix decreased by 11.41 %, 33.33 % and 40.28 %, respectively. This shows that MgO expansive agent can effectively reduce the autogenous shrinkage of UHPC.

Cao Fengze[12] studied the effect of MgO expansion agent on the shrinkage compensation performance of mortar. Through XRD quantitative analysis, the content of MgO and Mg(OH)2 at different ages was observed, and it was concluded that sufficient pore water was beneficial to the

precipitation of Mg(OH)2 crystals, which contributed to the expansion of mortar.

Zhao Shunzeng[13] discussed the mechanism of increasing the drying shrinkage of cement awards by water reducers. It is believed that the contact angle between the liquid phase and the capillary wall interface is the main factor affecting the drying shrinkage. The adsorption and arrangement of water reducers in the cement capillary wall will change the nature of the pore wall interface and increase the capillary pressure, resulting in an increase in drying shrinkage.

Wang[14] studied the effect of different dosage ( 0.1 %, 0.2 %, 0.3 % ) of SAP on the drying shrinkage of high strength concrete. With the increase of dosage, the drying shrinkage of concrete decreased gradually. Compared with the reference group, it decreased by 26.5 %, 40.2 % and 51.5 % respectively. It can be seen that SAP is a good reservoir, which can release free water and reduce the self-drying effect inside the mortar.

Zheng Hongjian[15] compared the autogenous shrinkage of concrete under dry and wet and pre-wet conditions of pottery sand. It can be found that the autogenous shrinkage of concrete group mixed with dry pottery sand increased by 21.4 %, 34.4 %, 36.0 % and 46.8 % respectively compared with that of concrete group mixed with pre-wet pottery sand. This shows that the concrete mixed with dry pottery sand is not as good as the concrete mixed with pre-wet pottery sand to improve the autogenous shrinkage.

Yu[16] studied the effect of different dosages of polycarboxylate, naphthalene and aliphatic water reducers on the early shrinkage of cement paste. Through mass loss test, mercury intrusion test and cement hydration test, the mechanism of water reducer was discussed. The results show that the three water reducers will increase the volume deformation of the paste, and as the dosage increases, the volume deformation increases. The main reason is that the water reducer can refine the pore structure and increase the number of small pores, resulting in increased shrinkage.

### 1.3. Research status of multi-regulation on volume deformation of cement-based materials

Liu Luming[17] used CaO expansive agent, SAP and shrinkage reducing agent in UHPC to reduce the volume shrinkage of concrete. The experimental results show that : although the single addition of CaO expansive agent can obtain sufficient expansion, it will lead to cracks in the sample due to excessive expansion. The addition of SAP can significantly enhance its expansion effect. The combination of the three can avoid excessive expansion and reduce the late autogenous shrinkage and drying shrinkage.

Zhao Haitao[18] studied the effect of the combined use of CaO expansive agent and zeolite on the mechanical properties and autogenous shrinkage of cementitious materials. The experimental results show that the addition of zeolite has a negative effect on the mechanical properties of HPC, but the combined use of expansive agent and zeolite has a significant synergistic effect on the autogenous shrinkage of concrete.

Cheng Shukai[19] used the internal curing effect of porous coral sand and the shrinkage reducing effect of shrinkage reducing agent to reduce the volume deformation of UHPC. The results showed that the two played a synergistic role in inhibiting the volume deformation of UHPC, and when the content of coral sand was 45 % and the shrinkage reducing agent was 1 %, the specimen had the lowest autogenous shrinkage and drying shrinkage.

Gong[20] found that the strength of UHPC at each age was higher than that of single-doped when the shrinkage reducing agent and the expansion agent were mixed. When 10 % expansion agent and 2 % shrinkage reducing agent were mixed, the synergistic effect of the two was the best. At this time, the mechanical properties of UHPC were the best, and the autogenous shrinkage and drying shrinkage were the least.

Xu[21] studied the effects of shrinkage reducing agent and saturated lightweight aggregate on the autogenous shrinkage and hydration process of UHPC. The results showed that both of them could reduce the volume shrinkage of UHPC. Due to the continuous release of internal curing water in lightweight aggregate, it could alleviate the self-drying effect of cementitious materials. At the same time, its porous structure had a certain adsorption effect on shrinkage reducing agent, and both of them had a positive effect on inhibiting the volume deformation of UHPC.

Zhang[22] found that compared with single-doped SAP, the co-doped shrinkage reducing agent and SAP changed the trend of continuous decrease of internal relative humidity. The autogenous shrinkage value decreased by 42.4 % compared with the control group, and the autogenous shrinkage rate also decreased, but the mechanical properties were slightly lower than those of single-doped SAP.

## 2. Conclusion

1.The addition of mineral admixtures is beneficial to reduce the volume shrinkage of concrete, but it is not the more the better. The optimal content of each mineral admixture has a certain range. There are few studies on nanomaterials at home and abroad. Nanomaterials as new mineral admixtures need to be further studied.

2.The addition of water reducing agent, expansion agent, shrinkage reducing agent and internal curing agent in concrete has a certain inhibitory effect on its autogenous shrinkage. Different admixtures have different optimal dosage and different inhibitory effects. In addition, the volume deformation of UHPC needs to be further studied by a variety of compounding combinations of four admixtures.

3.Most of the multiple materials have a better effect on inhibiting the volume shrinkage of UHPC than the single content, and have become the trend of the times. However, there are various combinations of multiple materials. Whether to adopt the combination of the two or the combination of the three or more remains to be further refined.

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