Effects of New Type Lime and Calcium Sulphoaluminate Expansive Agent on Deformation Properties of High Performance Concrete

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Abstract. According to the characteristics and structure of high performance concrete, influence laws of new type lime and calcium sulphoaluminate expansive agent on mechanical properties, deformation properties and microstructures of C50 concrete were investigated. The results show that with the increase of doped contents of new type expansive agent, shrinkage compensation effect on C50 concrete by expansion agent would increase as well. Limited expansion ratio of concrete with strength grade of C50 mixed with 6% expansion agent can meet the design values for post-pouring belt, expansion strengthening belt and other parts in the specification. C50 concrete can be more enhanced and compacted through mixing with 6% expansion agent. For those with age of 28d, after doped with 6% expansive agent, the pore structure of C50 concrete has been optimized. Ettringite and calcium hydroxide crystals from hydration reaction of expansive agent could be filled into the pore structures of C50 high performance concrete.

1. Introduction

With the development of concrete technology, high performance concrete has been widely applied in different types of architectures for it has superior and incomparable properties which ordinary concrete does not have [1]. However, concrete is hydraulic cementing material; for concrete has been placed in the natural environment since it was completed by pouring, in the process of hydrating and hardening, there must be autogenous shrinkage, drying shrinkage and temperature decrease shrinkage because of hydration reaction itself and dehydration of surrounding medium [2]. For high performance concrete is equipped with low water-binder ratio and high binding-material ratio, crack is increasingly serious, especially the crack caused by autogenous shrinkage at the early stage [3].

Volume expansion of expansion component, produced in the process of hydration, is applied to compensate the shrinkage of cement-based materials and is one of the important measures to reduce cracking and improve the stability of high performance concrete structure. Currently, ettringite is widely used as the expansion source to prepare expansive agent like sulphoaluminate ettringite in our country so as to compensate the shrinkage of concrete [4]. The expansion performance of this agent is mainly dependent on the content of free water and content of $Ca(OH)_2$ in the pore solution [5]. High performance concrete is characterized by low water-binder ratio and high-volume mineral admixtures. While $Ca(OH)_2$ is consumed by the mineral admixtures so that the alkalinity of solution in the paste of cementitious material declines, and it is bad for the formation of expansion product of ettringite. As the hydration products, calcium hydroxide and ettringite are taken as the expansion sources of compound expanding agent like lime and calcium sulphoaluminate compound expansive agent.In the hydration reaction of the agent, abundant $Ca(OH)_2$ is generated and it results in the increase of alkalinity of paste; in the condition of high alkalinity, many tiny ettringite crystals with high specific surface area may be produced by sulphoaluminate [6]. Lime and calcium sulphoaluminate compound expansive agent has become the research hotspot in the field that compensating the shrinkage of high-performance concrete and cracking control. According to the characteristics and structure of high performance concrete, **New Type Lime and Calcium**

Sulphoaluminate Expansive Agent is developed and researched by **Jiangsu Research Institute of Building Science**.

In the paper, the effects of new type lime and calcium sulphoaluminate expansive agent under different blending quantity on mechanical property and deformation performance of C50 concrete is studied, and microstructure is analyzed.

2. Experimental

2.1 Raw Materials. (1) Cement: Conch Cement P·O 42.5; (2)fly ash: grade II fly ash; (3)Aggregate: 5~25mm continuous gradation basalt; (4)Sand: yellow sand, fineness modulus 2.6; (5)Admixture: PCA®-I concrete-reducer; (6)expansive agent: New Type Lime and Calcium Sulphoaluminate Expansive Agent.

2.2 Mix Proportion. Concrete mixture proportions were shown in table 1. Designed value for strength grade of concrete was C50. The mixing amount of admixture could ensure the slump of fresh concrete which was between 160mm-200mm.

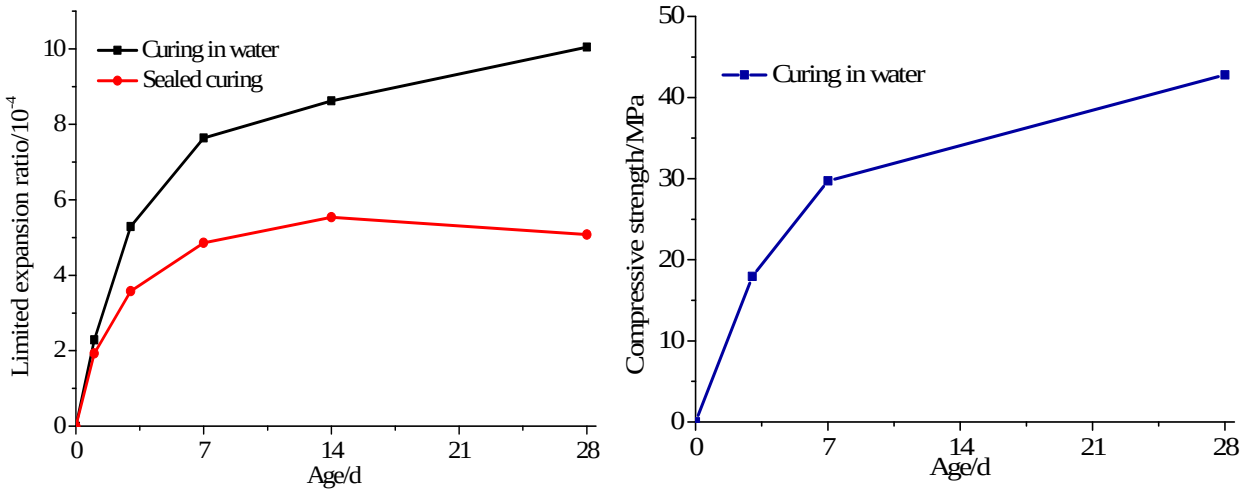
Table 1 Concrete mixture proportions

Samples	W/B	Concrete mixture proportions /(kg·m^{-3})					
		Water	Cement	Fly ash	Expansive agent	Sand	Aggregate
C50ref	0.35	168	384	96	0	761	991
C50Ea6	0.35	168	361	90	29	761	991
C50Ea8	0.35	168	353	88.5	38.5	761	991
C50Ea10	0.35	168	346	86	48	761	991

2.3 Experimental methods. Concrete compressive strength test was performed in accordance with GB/T 50081-2002 *Standard for Test method for Mechanical Property of Ordinary Concrete.* Test mold adopted 100mm×100mm×100mm. For conducting the restrained expansion rate test for cement mortar and concrete, referring to GB 23439-2009 *Concrete Expansion Agent.* Representation of the microstructure of C50 concrete could be performed by adopting environment scanning electron microscope.

3. Results and discussion

3.1 Influence of New type expansion agent on deformation properties of mortar. Under 20℃ water, limited expansion ratio of mortar specimens mixed with expansion agent (7d) is 7.64×10^{-4}. The compressive strength of 7d and 28d is 29.73MPa and 42.8MPa respectively, which comply with the requirement for type II product specified in the standard of *Concrete Expansion Agent* (see Figure 1).



（a）Limited expansion ratio of mortar　　（b）Compressive strength of mortar

Fig.1 Deformation properties and Strength of mortar doped with new type expansive agent

3.2 Influence of New type expansive agent on mechanical properties of C50 concrete. In Table 2, it showed the compressive strength of the C50 concrete mixed with 0%, 6%, 8% and 10% of expansion agent respectively in 3d, 7d and 28d. Under 20℃ water, with the mixing amount of expansion agent increasing, the compressive strength in 3d and 7d decreased. In curing age of 28d, the compressive strength of the C50 concrete mixed with 6% of expansion agent was higher than that of C50ref concrete. It showed that 6% of mixing amount of expansion agent has the function of filling pores and compacting concrete.

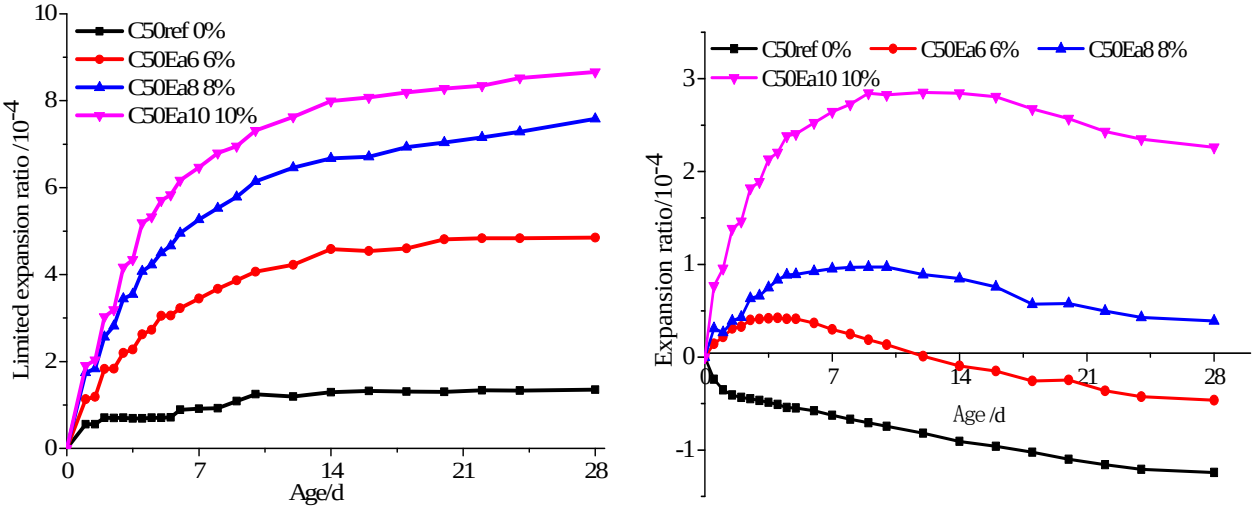
Table 2 Compressive strength of C50 Concrete doped wth different proportion of New type expansive agent

Samples		C50ref	C50Ea6	C50Ea80	C50Ea10
Compressive Strength/MPa	3d	38	36	33	30
	7d	55	54	48	42
	28d	63	66	58	50

3.3 Influence of New type expansive agent on deformation properties of C50 concrete. In Figure 2(a), it showed the limited expansion ratio of C50 concrete mixed with 0%、6%、8% and 10% of expansion agent respectively. Under 20℃ water, with the increase of the mixing amount of expansive agent, the C50 concrete deformation gradually showed expansion. At curing age of 14d, limited expansion ratio of concrete with strength grade of C50 mixed with 6% expansion agent could meet the design values for post-pouring belt, expansion strengthening belt and other parts in *Compensation Shrinkage Concrete Applied Technology Specification.*

The limited expansion ratio of C50 concrete mixed with more than 8% of new type expansive agent was great, which was well above the designed restrained expansion rate requirement in *Compensation Shrinkage Concrete Applied Technology Specification.* It could be caused by great expansion character of the prepared lime and calcium sulphoaluminate expansive agent.

In figure 2(b), it showed the autogenous volume deformation of C50 concrete mixed with 0%, 6%, 8% and 10% of expansive agent respectively. Under 20℃ sealed condition, with the increase of the mixing amount of new expansive agent, the autogenous volume deformation of C50 concrete showed expansion deformation. The expansion efficiency of the new expansive agent in 10d was basically played completely. And 10d later, the deformation of C50 concrete with different mixing amount of expansion agent showed similar shrinkage tendency with the increase of curing age.

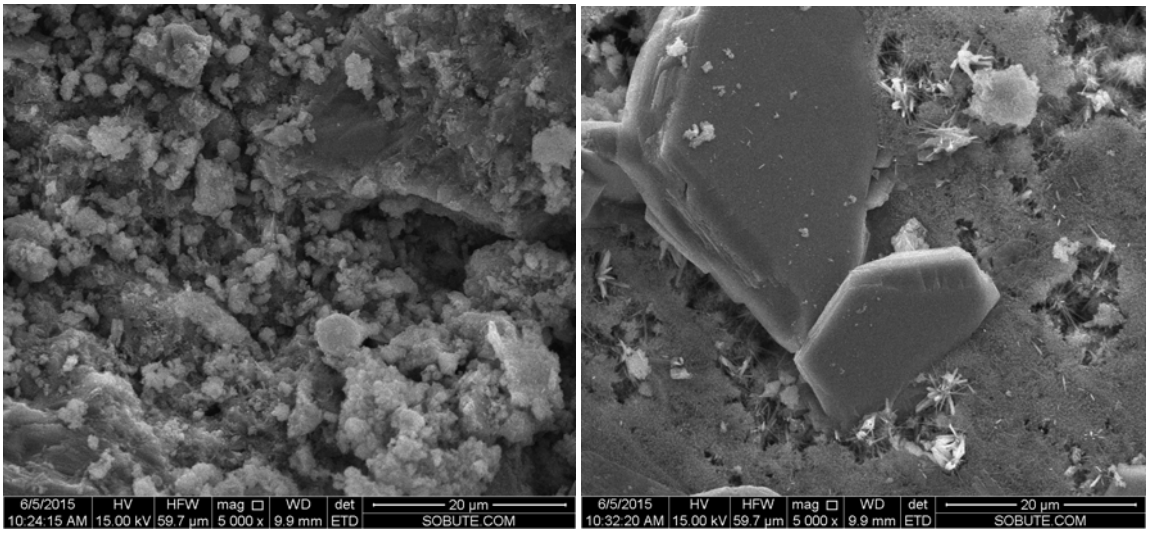


（a）Limited expansion ratio　　（b）Autogenous volume deformation

Fig.2 Effects of new type lime and and calcium sulphoaluminate expansive agent on deformation of C50 concrete

3.4 Influence of New type expansive agent on microstructures of C50 concrete. Based on the influence of different mixing amount of expansion agent on the deformation and mechanical property of C50 concrete, 6% of mixing amount of expansion agent had excellent cooperativity in these two

aspects. In Figure 3, it showed the microstructure of the cement paste of C50 concrete mixed with 6% of new expansive agent for 28d. At the age of 28d, compared with the cement paste of C50 concrete without expansive agent, the pore structure of cement paste was optimized; the ettringite and calcium hydroxide crystal produced by hydration reaction of expansive agent were filled in the pore structure of cement paste. Therefore, 6% of the mixing amount of expansive agent had the effect of enhancing and compacting C50 concrete.



(a)C50ref (b)C50Ea6

Fig.3 Microstructures of C50 concrete doped with 6% new type expansive agent by curing 28d

4. Conclusions

With the increase of the mixing amount of the new-type lime and calcium sulphoaluminate expansive agent, shrinkage compensation effect on C50 high performance concrete exerted by the expansion agent increases. The limited expansion ratio of the C50 concrete mixed with 6% of New type expansion agent could comply with the requirement of design values for structural parts, such as post-pouring belt, expansion strengthening belt and other parts in the specification.

(1) The expansion properties and mechanical properties of the new-type lime and calcium sulphoaluminate expansive agent could meet the requirement for type II product in the standard of *Concrete Expansion Agent.*

(2) Ettringite and calcium hydroxide crystals from hydration reaction of expansive agent could be filled into the pore structures of C50 high performance concrete.

(3) In the curing condition of 20℃ water, with the increase of content of new type expansive agent, deformation of C50concrete is gradually expansive. In the sealing condition of 20℃, autogenous volume deformation of C50 concrete doped with 8% expansive agent is still expansive deformation in the age of 28d.

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References

[1] D. M. Wang: *High Performance Expansive Concrete*, (China waterpower press, Beijing 2006).

[2] J.P. Liu, S.Z. Zhang, Q. Tian, et al: Deformation behavior of high performance concrete containing MgO composite expansive agent, Journal of Southeast University(Natural Science Edition), Vol.40, No.sup2 (2010), P 150-154.

[3] H.F. Hong, W. Sun, Y.S. Zhang, et al: Durability of concrete subjected to the combined actions of flexural stress, freeze-thaw cycles and bittern solution, Journal of Wuhan University of Technology, Vol. 23, No.6 (2008), P 893-900.

[4] A.Q. Lu, S.Z. Zhang, S.L. Tang: Deformation properties of cement pastes doped with new type lime and calcium sulphoaluminate expansive agent, New Building Materials, Vol. 6 (2014), P 29-32.

[5] P.K. Mehta: Mechanism of expansion associated with ettringite formation, Cement and Concrete Research, Vol. 3, No. 1 (1973), P 1-6.

[6] P. Yan, F. Jiang, P. Jiang, et al; Relationship beween delayed ettringite formation and delayed expansive in massive shrinkage-compensating concrete, Cement and Composite, Vol. 26 (2004), P687-693.