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Application of Mineral Admixture in High Performance Concrete

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I. Introduction

At present, the total consumption of commercial concrete in our country has reached 2.5 billion m^3 per year, and the output of cement has reached 2.6 billion tons, ranking first in the world for 20 consecutive years. So, china is a country with great cement production and concrete consumption. A large amount of CO_2 greenhouse gases (about 1.8 billion tons) are emitted in the cement production process, and industrial residues and wastes from iron and steel, electric power and geological and mineral industries in China amount to 1.05 billion tons annually, while the average utilization rate in concrete is less than 10%. Concrete industry has entered a new stage to reduce the consumption of energy and natural resources, improve the service life of concrete structures and reduce maintenance and repair costs. The energy conservation and emission reduction of concrete should first be reflected in the reduction of cement consumption, which needs to use all kinds of waste residue discharged every year to replace the cement with high energy consumption and high discharge in the production process. Rational application of mineral admixtures not only has achieved direct results in energy conservation and emission reduction, but has played an important role in promoting the development of high strength and performance concrete. Mineral admixtures can improve the micro-porous structure of concrete and the interface conditions between binder conditions between binder and aggregate. Thus, under the same water-binder ratio, the fluidity and late strength of concrete can be improved, the hydration temperature can be reduced, the shrinkage can be increased, and the volume stability of concrete can be enhanced. The concrete strength, impermeability, corrosion resistance and other durability indicators have been significantly improved, which plays a fundamental role in changing the conventional concrete performance. [1]

a) *High performance concrete and high strength and performance concrete*

High performance is a new requirement for concrete at an international conference in 1990. High performance concrete is also a basic direction of concrete technology development in the future. There are different definitions of high performance concrete at home and abroad, but they can be summarized as the following five aspects: (1) High durability. It is of long service life and small maintenance cost under normal service condition. Under special service conditions, it can meet the special requirements of anti-erosion, anti-freeze and thaw resistance in harsh environment. (2) High construction performance. It can smoothly complete the transportation and pouring of concrete under specific construction conditions, so that the concrete structure with superior compactness and uniformity can be obtained; (3) Higher strength. It is able to satisfy the strength requirement of design bearing capacity, and has enough capacity to increase strength in the later period to ensure that the strength of structural concrete does not shrink under normal conditions; (4) High volume stability. Concrete is not stratified and segregated before condensation, and its volume changes little after hardening, with good crack resistance; [2] (5) It can meet the requirements of environmental protection and sustainable development.

Of the above requirements, many are related to the compactness of concrete. Therefore, many materials take the relative index of measuring concrete compactness - chloride ion penetration resistance as an index to classify and test high performance concrete. High strength and performance concrete refers to high performance concrete whose strength grade is greater than or equal to C60.

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b) Main technical approach of preparing high performance concrete

1) Using high-quality mineral admixtures with large amount is the technical core of preparing high performance concrete. Because high performance concrete requires high compactness, and it is difficult to meet such requirements with a single cement as binding material. High-quality mineral admixtures must be used to repair and fill various micro-cracks in concrete by secondary hydration in the later stage. Practice in many units in our country shows that to prepare qualified high performance concrete, the mineral admixture content should reach at least 30%, and it is better to use it in combination. A large amount of concrete mixed with mineral admixtures also meets the requirements of environmental protection and sustainable development, as well as the basic condition for the preparation of green concrete. If the durability requirement of concrete is very high, a small amount of silica fume (3-5%) can also be added into concrete. For the silica fume's particles are very fine, it can infiltrate into the capillary pore of cement paste, and then carry out secondary hydration. In addition, its densification effect is very significant.
2) Low water-binder ratio is adopted. The high durability formed by high content of mineral admixtures can only be shown when concrete adopts low water-binder ratio, otherwise it may be counterproductive. For the limitation of low water-binder ratio, the current standards are different and generally less than or equal to 0.35-0.45, which may be related to the different scope of application for the standards. High content of mineral admixtures and low water-binder ratio should be two matching technical approaches.
3) To achieve high content of mineral admixtures and low water-binder ratio, water reducing agent with high quality and high efficiency is certainly required. Polycarboxylic water reducing agent developed and popularized in recent years is an ideal material, which not only has high water reducing rate and good plasticity retention, but the shrinkage of the concrete made by it is significantly lower than that of the concrete prepared with other types of water reducing agents, which can significantly improve the crack resistance of concrete.
4) In addition to the above special requirements, the selection of raw materials, mix design and production control of concrete should be strictly carried out in accordance with the requirements of the standards.

c) Effect of mineral admixture in high performance concrete

i. *Enhancement effect*

When mineral admixtures are added, the composition of cement paste's gelatinous substance can be improved; especially the free lime ($Ca(OH)_2$) can be reduced and removed. For SiO_2 in the active mineral admixture, $Ca(OH)_2$ and tobermorite with high alkaline can react pozzolanic reaction, which can produce tobermorite with low alkaline, higher strength and better stability.

ii. *Filling effect*

The average particle size of cement is 20-30 microns, while the average particle size of fly ash is 3-6 microns, and the silica fume is smaller than both of them, which is between 0.1-0.26 microns. It can fully fill the gap between the cement particles, so that the compressive strength and permeability performance are significantly improved. Close concrete prevents moisture from entering the interior of concrete. Freezing water in concrete is very scarce. Therefore, under the condition of freeze-thaw alternation, the frost resistance of concrete is greatly improved.

iii. *Reduction of hydration temperature peak effect*

After adding mineral admixtures, the amount of cement in concrete is reduced, so the calorific value of cement hydration in concrete is reduced. Although these active mineral admixtures will produce pozzolanic reaction and release hydration heat in concrete, this reaction lags behind the hydration reaction of the main body of cement and lasts a long time. This can restrain the early strength of concrete, but the later strength will not decrease.

iv. *Improvement effect of concrete durability*

1. Improve impermeability: The structure of cement paste and the interface between cement paste and aggregate are more compact, blocking the possible permeability pathway. 2. Reduce the harmfulness of alkali aggregate reaction: Due to the incorporation of mineral admixture, a large amount of calcium silicate gel with low alkalinity is formed in concrete hydrates. They can absorb and maintain large amounts of Na+ and K+ ions, thus greatly reducing the effective alkali content in solution of concrete pore. Therefore, the harmfulness of alkali aggregate reaction is greatly reduced. 3. Improve frost resistance: When water can't enter the concrete, the frozen water in concrete is very scarce. Therefore, under the condition of freeze-thaw alternation, the frost resistance of concrete is greatly improved.

v. *Relation of high fly ash content and reduction of alkalinity*

The possible negative effect of adding active mineral admixtures makes the alkalinity of concrete, the carbonization resistance of concrete, and the ability of protecting steel bar decrease. But the decline rate of

concrete alkalinity is not very fast. The research of Pu Xincheng and his students on the alkalinity of cement with large amount of fly ash shows that the PH values of fly ash are 12.56, 12.50, 12.46, 12.24, 12.15 and 12.06 respectively when the content of fly ash is 0%, 30%, 40%, 50%, 60% and 70%, which indicates that even if the content of fly ash reaches 70%, the PH value of cement mortar is still above 12, which is still higher than the lowest alkalinity value for reinforcement structure: 11.50. [3] When slag and other admixtures with high CaO content are added, their alkalinity is more guaranteed. The addition of active mineral admixtures improves the compactness of high performance concrete. Moisture, even O_2 and CO_2, are difficult to enter concrete, which also increases the ability of concrete to protect steel bar from erosion.

d) Green high performance concrete

1. More clinker cement is saved and environmental pollution is reduced. Because a large number of industrial residues are used for high performance concrete as active mineral admixture to replace a large number of cement, and these fine water-quenched slag and high-quality fly ash, silica fume or their composite materials become the main components of binding materials. Compared with the production of clinker cement, the emission of CO_2 is greatly reduced, and resources and energy are also saved.
2. Adding more active mineral admixtures (mainly industrial waste) is of advantages of improving the environment, saving land and limestone resources and energy, reducing the hydration temperature rise of concrete, and enhancing the volume stability and wear resistance.
3. Give full play to the advantages of high performance and reduce the amount of cement and concrete. By reducing the environmental burden fundamentally, concrete can become a sustainable building material as the largest artificial material in the contemporary era. It is the direction of concrete development and the future perspective of concrete.

Table 1: High strength and performance concretef increases with age

No.	Project Name and Age Limit	The Strength of Concrete Increases with Age				
		mf 28 (MPa)	mf 360 (MPa)	mf 5 years (MPa)	mf 10 years (MPa)	mf 14 years (MPa)
1	(Shenyang) Daxi Electric Industry Park In 1998	100.97	108.64	115.09	123.3	135.6
2	Shenyang Royal Wan Xin Hotel In 2001	116.39	126.5	139.2	157.3	
3	Shanghai Tower In 2012	118.7	131.9			
4	Shenzhen Ping'an Building In 2016	117.0				

Table 2: Concrete strength in each stage

No.	Date	Concrete strength (mpa) in each stage					
		28 Days	60 Days	360 Days	5 Years	10 Years	14 Years
1	2001.5.21	96.8		110.2	115.8	119.7	129.8
2	5.22	113.5	119.1	120.0	129.9	129.1	139.3
3	5.26	100.7		110.9	112.1	122.9	129.9
4	6.7	101.0		109.9	113.0	124.6	135.0
5	6.17	104.2		107.9	109.0	120.6	138.8
6	6.27	100.2		100.8	110.5	120.9	141.1
7	7.6	90.4		100.8	115.3	125.3	135.6
Mean values		101.0	119.1	108.6	115.1	123.3	135.6
Percentage increase in strength			117.92	107.52	113.96	122.08	134.26

Note: The 5-year strength specimens obtained from 3-5 groups of mean values.

Table 3: The long-term strength of C80 concrete in Daxi Electric Industry Park

Huaneng-Xiaoyettian P II 52.5	AdmixtureZ-3	AdditiveJL118	Medium Sand of Hun River	Gravel of Liaoshang 5-25 mm
Water cement ratio0.28 500 kg/m3	70 kg/m3	4 % 22.8	813	954

II. Conclusion

At present, our scientific work should be transformed from maximizing wealth from nature to properly using resources, protecting environment and maintaining ecological balance. The development and application of high performance concrete will be the goal of several generations of workers for concrete. Now, the situation is very favorable, that is, it draws great attention from Standard Quota Department of the Ministry of Housing and Urban-Rural Construction and the Raw Materials Industry Department of the Ministry of Industry and Information Technology. The Building Material Research Institute of China Academy of Building Research has compiled *Technical Guide for the Application of High Performance Concrete*, and approved and issued *Technical Specification for the Application of Mineral Admixture* GB/T51003-2014, which has been "applied for approval for nearly eight years". Although the condition mentioned above is very good for popularization and application of high performance concrete, the measurers can't be taken hastily. At present, the quality of raw materials in various places is very poor, and it is difficult to reduce the water consumption of certain type of concrete. So, it is necessary to carry out popularization and application of high performance concrete steadfastly.

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