FOR SUSTAINABLE DEVELOPMENT: TO PRODUCE CEMENT BY ANOTHER CONCEPT

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Abstract

From the discussion of some accidences of concrete preparation taking place on site and the current situation of cement production in China, an argument is introduced that production of cement by another concept is beneficial to improvement of properties of cement and concrete and sustainable development of cement industry. Some operation processes of concrete can be moved into factory. It can optimize much accurately the composition and properties of cementitious materials used for preparation of concrete. Three issues must be considered for the production principle of new cement: (1) Hydration characteristics of new kind of cement, (2) particle size distribution of new kind of cement, and (3) compatibility of chemical admixtures and hydraulic constituents in new kind of cement. Some new properties proofing methods and standards must be developed to enhance the utilization of this new cement.

1. Introduction

High volume fly ash concrete developed by Malhotra and his colleagues (1, 2) is coming be well known in China. A typical example is the application of high performance concrete in the project of Shenzhen subway tunnel (3). The underground soil of Shenzhen contains moderately aggressive medium such as SO_4^{2-} and Cl. The conventional concrete cannot satisfy the designed requirement of durability for the structure of Shenzhen subway. High volume mineral admixture concrete was

suggested by Tsinghua University, firstly. A full-scale section mock up was constructed in 1999 to investigate practical possibility, mechanical properties and durability of this new type of concrete in aggressive coastal environment with hot and moist weather. The designed compressive strength class is C30. The mix proportion of this concrete is: ordinary portland cement OF PO-42.5 (containing less than 15% of mineral admixture) 180 kg/m^3, fly ash 180 kg/m^3, ground granulated blast-furnace slag 80 kg/m^3, W/B 0.42. This concrete showed excellent workability, mechanical properties and durability. A barrier wall was built with this concrete for a vehicle terminal of Shenzhen subway in 2002.

Everything is in two aspects. Superiority and deficiency exist simultaneously. High performance concrete with good properties has complex binder composition. Multi-constituent would make troubles for managing of production, purchasing and batching of raw materials as well as controlling of quality. Once in a building site, a worker was mistaken to add fly ash as cement into mixer. As a result, of course, the columns cast with the falsely proportioned concrete had no strength and mould be pulled down. Therefore, fly ash does not be used any longer in the project of this company, even though the managers know the advantages of fly ash. About 3 years ago, another similar accident also happened, but that mistaken was between fly ash and superplasticizer. It resulted in a part of concrete no setting after 5 days.

These accidents force people to think a question. Why don't we produce a type of cement containing all cementitious materials and chemical admixtures used for concrete to simplify the manufacture process of concrete in site? The fluctuation of concrete quality can be decreased by the way of using high-quality raw materials produced through a strictly controlled process in factory. We should change our traditionally angle of view on the relationship of cement and concrete. It can be considered that to produce cement according to requirement of concrete practice and to examine quality of cement according to regulation of concrete use is urgent affairs.

2. The Current Relationship of Cement and Concrete in China

More than 0.7 billion ton of cement was produced in China in 2002. Among those, more than 50% is ordinary portland cement (containing less than 15% mineral admixture), about 40% is slag portland cement (containing normally 20%-40% ground granulated blast-furnace slag); the others include fly ash portland cement, composite portland cement and special cements. The slag content in Chinese slag portland cement is rarely more than 40% although 70% of substituting ratio is allowed by national standard. The production of fly ash portland cement is even rare in China. It is always used for masonry as a low class of product.

Relational ISO standard has been accepted in China since 2001 to verify the quality of cement. Strength of cements blended with high volume of mineral admixture shows lower especially in early ages than that of ordinary portland cement because a uniform water-cement ratio of 0.5 is used for testing strength of all kinds of cements. Concrete producers do not welcome blended cements with high volume of mineral admixtures due to their low strength, especially in early age. They prefer to add fly ash into concrete in situ to improve workability and economy of concrete. They only ask for cements with quickly hardening and high strength to satisfy the strict demand of high constructing speed, but disregard other properties of cement. Therefore, cement producers do their best to enhance cement strength. The main technologies for increasing strength, especially in early age, of cement are rising of content of C_3S and C_3A in clinker and increasing of special surface of cement. Both producers of cement and concrete do not understand the opposite side each other, and do not know really what the actual requirement of concrete structure is. Both them do not know what would happen while such cement were used in concrete. There is a high risk to crack with the concrete. Compatibility between cement and superplastisizer might be another problem. Workability and durability of the concrete could be impaired.

3. The Conventional Concepts Need to be Changed

Strength is considered as the most dominant index for the qualification of cement for a long time. Therefore, cements involving high volume of mineral admixture are classified in the range of low quality. Actually the quality index of products should be homogeneity and uniformity. Strength of cement examined by the standard method is only an index to reflect the stabilization of producing process in a factory and to compare the relative quality difference of cement among different factories. It does not present the properties of cement when it is used to prepare concrete. Judging the cement quality rightly must concern not only strength but also other characteristics of cement. When we inspect the properties of cement based on the mechanical properties, workability and durability of concrete simultaneously, strength and fineness of cement need not be so high and more mineral admixture can be involved into cement. Thus, more raw materials with lower quality can be used, more mineral admixture can be involved in cement, less energy is resumed and less greenhouse gas is exhausted during the cement manufactory. It benefits the discharge of ecological load for our world.

Cement producers concern little about the preparation of concrete, otherwise, concrete engineers understand little about the cement chemistry in the last century. Then there is not serious trouble because the concrete mixture was simply consisted from cement, aggregate and water; and its strength class was not high. Nowadays the new types and the new constituents of concrete continuously emerge along with the progress of science and technologies. Modern concrete is much more complex than that before a few decades. At present-day, concretes with different strength classes can be made using the same kind of cement, whereas, concretes with same strength class can be made using cements with different strength classes. Sometimes more than 10 kinds of material are included in a concrete mixture. It is very difficult for the engineers in site or in ready-mixing station to know the characteristics of all materials and to determine an appropriate proportion of concrete mix. Thus, there is an increasing demand to supply ready-mixing station a ready cementitious material to

simplify the mixing procedure and quality-controlling system of modern concrete. Some pioneering attempts have been done in Canada, Russia, and China (4-7).

4. Producing New Types of Cement by Another Concept

First of all we must answer two questions. One is which principle is based to produce new types of cement. Another is how the properties of cement are examined.

4.1. The principle based to produce new types of cement

Looking back the history of cement and concrete, it is found that concrete was developed based on the properties of cement that was previously invented. It is already observed that some hydration productions and paste structure of traditional portland cement is not beneficial to durability of concrete structure. Demand of concrete must be fully considered in the producing process of new kind of cement. It is not too simple to mix all raw materials and grind the mixture together. Three issues must be considered.

1) Hydration characteristics of new kind of cement: Optimization of SO_3

The composition and production of new type of cement must conform the principle of sustainable development. The new cement should be constituted with less clinker but more supplemental cementitious materials discharged from other industry as waste. Its hydration characteristics are different from the traditional portland cement. For example, gypsum plays a role not only as the setting regulator, but also an activator to enhance the potential hydration activity of supplemental cementitious materials involved in new cement and would control shrinkage of concrete by suitable dosage . Because the SO_3 content is inadequate in concrete adding high volume mineral admixture in situ, when the new kind of cement will be produced in factory, SO_3 content in cement must be optimized to fulfill the above-mentioned tasks.

2) Particle size distribution of new kind of cement: Optimization of constitute and Ground process

Besides the composition, particle size distribution is another impotent factor influencing the properties of cement. Conventional blended cement produced in China is ground mainly by means of collective pulverization of all constituents. The

hardness of constituents blended in cement is greatly different from each other. Thus, a perfect particle size distribution of cement is not easy to obtain with the process of collective milling. For example, when a blended cement constituted of clinker and granular blast-furnace slag is ground collectively to special surface of 350 m^2/kg, the fineness of ground granular blast furnace slag is only about 220m^2/kg due to its higher hardness, while clinker will be over-ground in this case. One of results from this situation is that clinker will hydrate too quickly, contrarily slag functions like an inert material. It results in bleeding of fresh concrete and low strength development of hardened concrete. Therefore, conventional blended cement is not considered as a top-quality product. The advanced production of blended cement is that clinker and mineral admixtures are ground separately. The process can be optimized to obtain the perfect particle size distribution with lest energy consume based on the grindability of each constituent of blended cement. Besides, if fly ash and granular blast-furnace slag were blended together with clinker, fly ash and slag could be grinding aids each other.

3) Compatibility of chemical admixtures and hydraulic constituents in new kind of cement: Process for adding the chemical admixtures

The new type of cement may contain the same uniform chemical admixtures to modify the efficiency of production and the properties of cement. Same chemical admixtures added into concrete when it is prepared in ready-mixing station can be added into the cement now. This procedure simplifies much the production and quality controlling system of concrete in situ. One of the problems facing concrete engineers in recent years is that more and more chemical admixtures are used to produce modern concrete. Same of them is not always compatible with modern cement. It results in poor workability of fresh concrete. The causation of compatibility of chemical admixtures and hydraulic constituents is complex and difficult to control by an inexperienced engineer in situ. Quality and quantity of chemical admixture can be finely determined through a lot of experiments and theoretical analysis when they are added into cement in factory. The optimal compatibility can be confirmed during this production process.

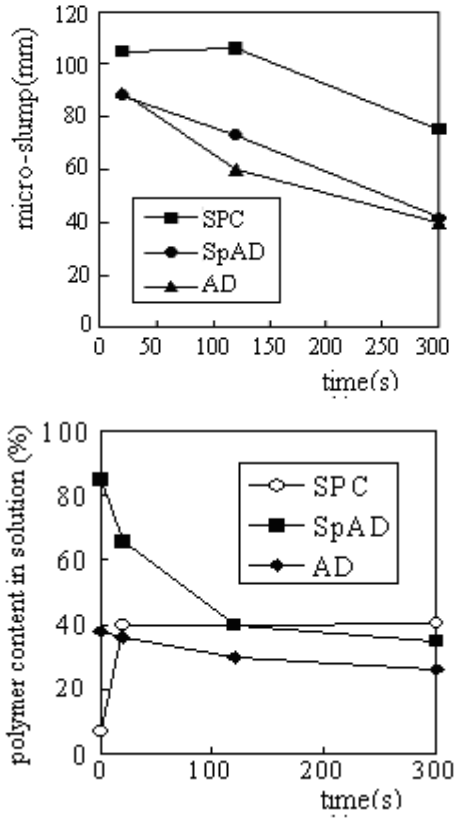

Fig. 1: Efficiency of chemical admixtures when adding process varies

It was reported by Rossetti et al. (8) that efficiency of chemical admixtures is different by various adding process as shown in Fig. 1. SPC is a cement sample with superplastisizer added during producing of cement, SpAD is the sample with superplastisizer added into cement product, and AD is the sample with superplastisizer added into mix water during the preparation of concrete. Water reducing efficiency of sample SPC is better than that of both SpAD and AD.

4.2. The methods and standards to verify the properties of new kind of cement: To select w/c according to regulation of concrete practice

With optimized added way and dosage of superplastisizer, compounding of constitutes involving mineral admixture and clinker, water demand for normal consistence of cement paste can be 15%-20% depended on raw materials used, which differs greatly from traditional cement. If the ISO strength verifying method is used to determine the strength of new cement, the mortar is too soft to be cast. Water demand for molding of new cement should be determined according to the normal consistence of mortar. It reflects the real using situation of cementitious materials in concrete. The method and standard to proof the properties of a material need not be constant with ones to control the production process of the material. For example, dry mortar is also a kind of cementitious materials, but its properties are proofed with the methods differing obviously the ISO testing methods of cement.

5. Example

Table 1: Properties of new kind of cement

Water demand (%)	Setting time (h:m)		Hydration heat (kJ/kg)		Flexural strength		Compressive strength	
	Initial	Final	3d	7d	3d	28d	3d	28d
17.6	4:59	7:00	144	180	5.2	10.4	33.7	67.6

The above mentioned new cement has been studied and cooperating with Concrete Co. of City Construction Ltd., Beijing, a product of pilot-plant test has been used to prepared concrete of C30 and C40 for constructing a inner wall and cover board of first step underground garage of Meilin apartment building in Beijing.

After optimizing, that cement consists of 40% of fly ash, 10% of slag, and 6% of gypsum besides 50% of portland cement clinker. Properties of that cement are shown in Table 1. The principal properties of concrete made by that cement is shown in Table 2. It has been proved by experiments and practice that the technical path mentioned above is feasible.

Table 2: The principal properties of concrete made by new kind of cement

Concrete	Slump (mm)	Slump loss After 1h (mm)	Setting time (h:m)		Compr. strength on 28d (MPa)	Shrinkage on 28d (%)	Carbonated depth (mm)
			initial	final			
C40	220	15	13:41	15:21	52	0.017	6
C30	215	10	12:12	14:23	38		

6. Conclusions

- For sustainable development, production of cement should be considered to fulfill regulation of concrete structure practice, so that the traditional concept on that strength must be changed to be beneficial to durability of concrete structure under various environmental conditions.
- High volume mineral admixture concrete is an effective way for sustainable development of concrete. Production of cement should be seasoned with this requirement. For simplifying the mixing process of concrete in situ to eliminate the occasional operating mistakes, Some operations of concrete production would be moved into cement plant to optimize much accurately the composition and properties of cementitious materials used for preparation of concrete. In this way, the composition and properties of cementitious materials used for preparation of concrete can be optimized much accurately.
- Examination of cement for quality control of product should be also considered according to regulation of concrete practice. Some new properties proofing methods and standards must be developed to enhance the utilization of this new cement.

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