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PREFACE

Sponsored by the Chinese Ceramics Society, the Fifth International Symposium on Cement and Concrete (5th ISCC), formally known as the 4th Beijing International Symposium held in 1998, is held in Seagull International Convention Center in Shanghai, P. R. China on from October 28 to November 1, 2002.

The objectives of the symposium are to review the progress in the fields of cement and concrete since the 4th Beijing International Symposium held in 1998, and to exchange the achievements of related scientific research throughout the world, thus to promote the sustainable development of cement and concrete industries in the 21st century.

Committed by the 5th ISCC Scientific Committee, we have the pleasure of taking the editing work of the symposium proceedings, which comprise 202 papers to be presented at the symposium, among which 67 papers are from foreign countries and 135 from China.

The proceedings in two volumes cover five themes, namely the technology and equipment of cement manufacture; fundamental research and experiment methods; blended and special cements; industrial wastes and by-products used in cement and concrete industry and concrete and its products.

At the moment of the publication of the proceedings we would like to express our sincere thanks to the individuals and organizations who have generously provided financial support to the symposium which makes it possible to host the symposium and publish the proceedings, and who have taken active part in reviewing of the papers.

Professor Yao Yan
The Scientific Committee of the 5th ISCC
Shanghai, P. R. China
October 28, 2002

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on the Cement and Concrete
Shanghai, China, Oct. 28~Nov. 1,2002

ADVANCED CEMENT-BASED MATERIALS

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ABSTRACT This paper discusses the changes in chemistry and microstructure that are the basis of advanced cement-based materials. The paper considers both processing required to achieve high performance with particular reference to systems densified by particle packing at the micron level, as well as the interrelationships between microstructure and properties. Modification of the cement-based matrix by fibers or polymers is also discussed.

Key words DSP cement; fiber-reinforcement; MDF cement

1 INTRODUCTION

Over the past twenty years concrete materials scientists and engineers have been steadily pushing the limits to the strength of cement-based materials. It is now possible to produce composites with compressive strengths exceeding 400 MPa, and tensile strengths greater than 200 MPa. However, it is now recognized that the issues of ductility and durability are more important than strength *per se*, so that it is important to understand how performance is linked to the chemical and physical make-up of the material. This paper attempts to summarize the current knowledge regarding the performance of advanced cement-based materials. Three distinct approaches have attracted considerable research effort in recent years. They are:

(1) Dense, particle packed systems (e. g. DSP cements) that preserve castability while using very low water contents [1];

(2) High volume, fiber-reinforced composites to provide a high degree of ductility and strength[2];

(3) Reactive cement-polymer composites (e. g. MDF cements) which harness the complementary properties of polymeric materials [3].

The first system will be discussed in more detail since these systems are being used commercially and illustrate most of the important principles underlying the control of high performance in concretes.

2 FORMULATION OF DSP

2.1 Processing

It is a challenge to produce castable cement-based composites with low water contents because of the negative impact on workability. High cement contents are required to maintain adequate workability, and with the use of superplasticizers concretes can be successfully produced and placed with a w/cm as low as 0. 35. To achieve lower values requires the use of mineral admixtures in conjunction with superplasticizers (as summarized in Table 1). Fly ashes with suitable spherical morphology can improve workability and lower the w/cm values to 0. 3 in favorable cases, but to achieve lower water contents requires the use of silica fume because its sub-micron particle size allows it to pack between the cement grains. In this way spaces between cement grains that would normally have to be occupied by water are partially filled with other solid particles. This is the basis of castable DSP (Densified with Small Particles) systems which can have w/cm as low as 0.16 [4,5]. Only a 6 wt.% replacement of cement by silica fume can be effective [6]; larger replacements give quickly diminishing improvements, but can be used to control the phase composition of the hydrated paste matrix.

DSP systems require careful attention to processing in order to realize the full benefits of particle packing. Strengths can be more than doubled without changing the formulation simply by changing processing strategies (Table 2). High doses of superplasticizer are required, typically 2wt.% ~3 wt.% for the sulfonated naphthalene formulations, to successfully disperse both cement and silica fume, although the newer polycarboxylate admixtures are more effective. Separate mixing of the paste components under high shear seems to be the most efficacious form of processing. It is also necessary to avoid using densified fumes. These have been mechanically agglomerated (Fig. 1) and cannot be fully dispersed chemically, or by conventional mixing. Incomplete dispersion can lead to performance problems under certain circumstances [7]. Further densification by pressure dewatering is required to reduce w/cm ratios below 0.15. In this way, w/cm <0.10 and compressive strengths exceeding 400 MPa can be attained [5].

Table 1 Characteristics of Concretes

	Regular	High Strength	V. High Strength	DSP
Compr. Str. (MPa)	<50	50~100	100~150	150
w/cm	>0.45	0.45~0.30	0.30~0.25	<0.25
Admixtures	NR#	WRA/SP*	SP	SP
Chemical mineral	NR	Fly ash	SF*	SF
Permeability (m/s)	$<10^{-12}$	10^{-13}	10^{-14}	$<10^{-15}$

NR = not required;

* WRA = conventional water-reducing admixture;

SP = superplasticizer; SF = silica fume.

Table 2 Processing Strategies to increase compressive strength (w/cm = 0.2)

Conventional mixing	
with SP#	100 MPa
with SP + SF	125 MPa
SP + SF + de-airing	175 MPa
Pre-blending of solids + de-airing	
SP only	170 MPa
SP + SF; no reaction of SF	~240 MPa
SP + SF reacted at 25°C	310 MPa
as above. dried at 200°C	350 MPa

SP = superplasticizer;

SF = silica fume.

2.2 Particle packing

Effective particle packing depends on the relative size of particles and the number of different sizes [8]. Ternary systems can give denser packings than binary systems (see Table 3) and the relative particle size should not be greater than 10 : 1 for each size classification. Therefore in binary systems, if the mean cement particle size is 15 μm, then the particle size of the smaller packing phase should not exceed 1.5 μm. In principle calcined clays, such as metakaolin, should be able to achieve dense packings; but these materials are not as effective because of their platy morphology. The spherical morphology of silica fume particles, and the high relative size ratio (100 : 1), makes it the optimum choice However, although smaller sizes do not give theoretically denser packings, they make it easier to approach the theoretical values more closely in practice. Nevertheless, long mixing times (> 10 min) are needed to give good packing.

2.3 Hydration chemistry

While particle packing is a purely physical phenomenon, silica fume is also a highly reactive pozzolan and modifies the hydration of the cement. Initially silica fume accelerates the hydration of alite and thus partially offsets the set retardation caused by the high dosage of superplasticizer. Later silica fume reacts pozzolanically with both calcium hydroxide and high-lime C-S-H gel formed by the hydration of alite and belite to giver a low-lime C-S-H gel with the approximate composition CSH_x. The actual composition of C-