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Biomass fly ash in concrete: SEM, EDX and ESEM analysis

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Abstract

This document summarizes microscopy study of concrete prepared from cement and fly ash (25% fly ash and 75% cement by weight), which covers coal fly ash and biomass fly ash. All the fly ash concrete has the statistical equal strength from one day to one year after mix. Scanning electron microscopy (SEM), Energy dispersive X-ray (EDX) and environmental scanning electron microscopy (ESEM) analysis show that both coal and biomass fly ash particles undergo significant changes of morphology and chemical compositions in concrete due to pozzolanic reaction, although biomass fly ash differs substantially from coal fly ash in its fuel resources.

Keywords: Biomass fly ash; EDX; SEM

1. Introduction

Biomass-coal cofiring enjoys overwhelming advantages in terms of cost, efficiency, technical risk and implementation time among renewable energy options for power generation in many regions of the world. However, current American society for testing and materials (ASTM) and American concrete institute (ACI) standards preclude none coal derived fly ash from use in concrete. This investigation studies the pozzolanic reactivity of biomass (and coal) fly ash in concrete through a variety of image and chemical analyses.

This document is written in a chemical composition shorthand common to the concrete industry but foreign to the great majority of chemists and chemical engineers. This shorthand notation is useful because the detailed chemical composition of the reactants and products in any practical concrete application are both cumbersome and only approximately known. Table 1 summarizes the correspondence between traditional chemical specifications and the shorthand notation used in this document and will be especially useful for those unfamiliar with the traditional nomenclature used by the concrete community.

The cement hydration reactions contain the hydration of calcium silicates, tricalcium aluminates and ferrite phase. The hydration of calcium silicates (take C_3S as an example) produces C–S–H gel and CH, as follows [1]:

$$2C_3S + 11H \rightarrow C_3S_2H_8 + 3CH \quad (1)$$

The Ca/Si ratio in C–S–H gel varies in a wide range, but normal values lie between 0.8 and 2.1, with an average of 1.5 [2]. The other cementitious reaction product, CH, forms a layered (often referred to as laminar) cement paste [2].

Pozzolanic reactions refer to chemical reactions between active SiO_2 and the CH, as follows [1]:

$$CH + S + H \rightarrow C\text{–}S\text{–}H \quad (2)$$

The stoichiometric coefficients of this reaction are not fixed. The complicated reaction network summarized above leads to a variety of products collectively called C–S–H gels, similar to the products from cementitious reaction illustrated in Eq. (1).

C–S–H gels account for the main strength of concrete, with CH contributing little to concrete build up; for pozzolanic reactions in this paper, fly ash combines and

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Table 1
Abbreviations of cement compositions in civil engineering field

Abbreviations	C	S	A	F	M	K	N	$\overline{S}$	$\overline{C}$	H
Actual meaning	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	Na_2O	SO_3	CO_2	H_2O

consumes CH and forms new C–S–H gels, which contribute more to the strength build up of concrete.

2. Experimental procedures

A suite of concrete samples that represent the range of properties likely to be encountered during biomass cofiring with coal provide the baseline data for this document. The cementitious portion of these samples contains neat cement as control and coal fly ash replacing 25% cement by mass. The fly ash has four resources: (1) coal fly ash, including Class C and Class F; (2) wood fly ash from pure wood combustion; (3) blended biomass fly ash that cover Wood C (80% Class C blended with 20% wood fly ash by mass) and Wood F (80% Class F blended with 20% wood fly ash by mass); and (4) cofired fly ash that cover SW1 (80% Galatia coal fired with 20% switchgrass by mass) and SW2 (90% Galatia coal fired with 10% switchgrass by mass). The detailed properties of fly ash and fly ash concrete including mix design, strength, freezing and thawing and rapid chloride permeability appear elsewhere, which indicate that in related to all the above properties tested, biomass fly ash (except pure wood) has equal or better performances than coal fly ash in concrete [3,4].

Image analysis of specimens obtained from fragments of concrete samples used primarily for compressive strength analyses provide a sample suite for this investigation. Images primarily from unpolished surfaces of these fragments allow evidence of crystallization and other chemical

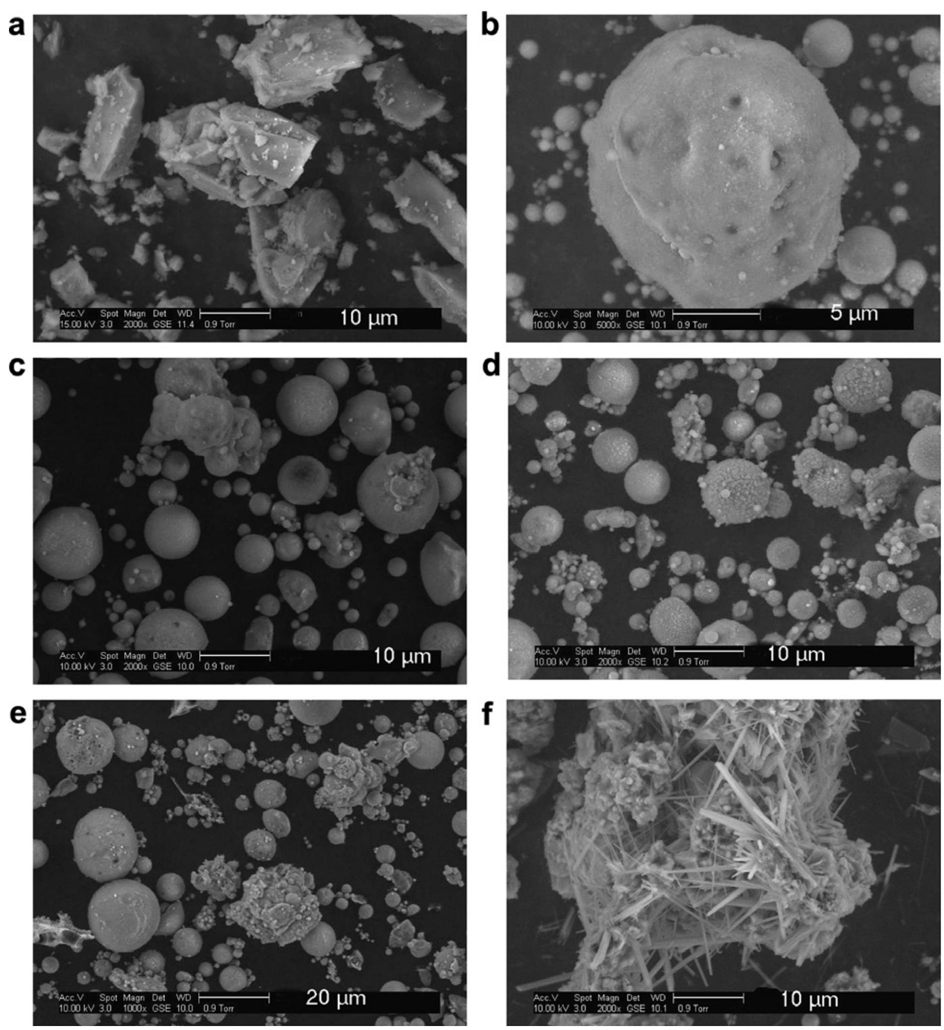

Fig. 1. Scanning electron micrographs (SEMs) of cement and fly ash. (a) Cement; (b) Class C; (c) Class F; (d) SW1; (e) SW2 and (f) Wood.