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Combined effect of expansive and shrinkage reducing admixtures to obtain stable and durable mortars

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Abstract

In order to improve the dimensional stability of cement based mortars, the effects produced on cement hydration of a shrinkage reducer (propyleneglycol ether based—SRA) and an expansive admixture (calcium oxide based—EXP) were investigated. Mortar samples (prepared without admixtures or with SRA or EXP or SRA and EXP) were compared through compressive strength measurements, water evaporation, restrained shrinkage and restrained expansion measurements. Setting time and free expansion were also detected on cement paste specimens.

A synergistic effect on the shrinkage reduction was observed when the shrinkage reducing admixture and the expansive agent were used together. In order to clarify this phenomenon, the hydration of cement pastes containing these kinds of admixtures was followed by ESEM-FEG (environmental scanning electron microscopy–field emission gun), TG (thermogravimetry), specific surface area measurements (by BET—Brunauer–Emmet–Teller-method) and XRDS (X-ray diffraction spectroscopy).

Keywords: Calcium oxide; Expansion; Expansive admixture; Shrinkage; Shrinkage reducing admixture

1. Introduction

The exposure of a cement based system to non-saturated environment (RH < 100%) causes drying shrinkage due to water evaporation [1]. Shrinkage is one of the main reasons of mortar failures like curling, cracks formation and debonding. Many authors have underlined the importance of dimensional stability to extend the service life of concrete structures [2,3]. Today, several methods are available to limit shrinkage: (1) expanding and non-shrinking cements [4], (2) surface treatments [5], (3) shrinkage reducing admixtures (SRA) [6] and (4) expansive admixtures [7]. In the present paper, only the last two techniques will be evaluated as a means to obtain cement systems with high dimensional stability.

2. Experimental

The study was performed by detecting mechanical, morphological and chemical properties of mortars or cement pastes having variable composition: without admixtures, with 3% (by cement mass) of an expansive agent, with 3% of a shrinkage reducing admixture and with 3% of both admixtures. The mortar specimens were characterised measuring compressive strength development, air content, unit weight, mass loss during hardening, restrained shrinkage and restrained expansion. Setting time and free expansion were determined on cement paste samples. Furthermore, restrained shrinkage and restrained expansion were also followed on other mixture compositions: 8% (by cement mass), 6%, 4%, 2% of an expansive agent; 4%, 3.5%, 2%, 1.5% of a shrinkage reducer; and different their combinations. The influence of such chemicals on cement hydration was studied by: ESEM-FEG (environmental scanning electron microscopy–field emission gun), specific surface area measurements (BET—Brunauer–Emmet–Teller-method),

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Table 1
Clinker mineralogical composition (determined according to ENV 196/2)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO
22.1%	3.2%	4.9%	65.2%	2.0%

thermogravimetric analysis (TG) and XRDS (X-ray diffraction spectroscopy).

2.1. Raw materials

A cement type I 52,5 (according to ENV 197/1—Table 1), a propyleneglycol ether as shrinkage reducing admixture (SRA) and a calcium oxide based expansive agent (EXP) were employed for mortar and cement paste preparation. The selected properties of the admixtures are shown in Table 2. A standard (ENV 196/1) silica sand (0–2.5 mm) was used.

2.2. Mechanical tests

The mixture compositions are reported in Table 3. The mortar specimens were prepared and stored according to ENV 196/1 (40 × 40 × 160 mm). Compressive strengths were determined at 24 h, 7 and 28 days (each result is an average of six measurements). Air content (DIN 18555—each result is an average of three measurements) and unit weight (by picnometer—each result is an average of three measurements) were detected on fresh made mortar samples (0% admixture, 3% EXP, 3% SRA and 3% EXP + 3% SRA). Restrained expansion was measured according to UNI 8148 (drawn from ASTM C 845-90) by a digital length comparator Mitutoyo Model IDC 112B: three (80 × 80 × 240 mm) samples provided with metallic reinforcement (made of a 240 mm steel rod, passing through the specimen and welded to two metallic plates) were cured for 8 h at 20 °C and 95% RH; the specimens were demoulded and conditioned in water; the restrained expansion data were calculated with respect to the initial steel rod length and measured from 24 h until 28 days after mixing. Restrained shrinkage was carried out as already described for the restrained expansion test with the difference that, after 8 h at 20 °C and 95% RH, the specimens were kept in a dry environment (23 °C and 50% RH). Water evaporation was determined by mass loss measurements on cylindrical samples (each result is an average of two measurements—

Table 2
Admixture properties

Admixture type	Characteristics	
Expansive (EXP)	Chemical composition (%)	90 CaO, 10 $CaCO_3$
	Specific gravity (kg/l)	0.8
	Material retained on a 80 μm sieve (%)	98
Shrinkage reducing (SRA)	Chemical composition (%)	100 propyleneglycol ether
	Density (kg/l)	0.91

Table 3
Mixture compositions

Component	Mortars																Cement pastes			
	0% Admixture	8% EXP	4% SRA	8% EXP+ 4% SRA	6% EXP	3.5% SRA	6% EXP+ 3.5% SRA	4% EXP	2% SRA	4% EXP+ 2% SRA	3% EXP	3% SRA	3% EXP+ 3% SRA	2% EXP	1.5% SRA	2% EXP+ 1.5% SRA	P (0% admixture)	P (3% EXP)	P (3% SRA)	P (3% EXP+ 3% SRA)
Cement (g)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Normalised sand (g)	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	–	–	–	–
EXP (g)	–	8	–	8	6	–	6	4	–	4	3	–	3	2	–	2	–	3	–	3
SRA (g)	–	–	4	4	–	3.5	3.5	–	2	2	–	3	3	–	1.5	1.5	–	–	3	3
Water/cement ratio	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.35	0.35	0.35	0.35