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Mineral admixtures in mortars effect of type, amount and fineness of fine constituents on compressive strength

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Abstract

This work is the third part of an overall project the aim of which is the development of general mix design rules for concrete containing different kinds of mineral admixtures (also named mineral additions or mineral constituents). It deals with the compressive strength of mortars made with up to 75% of crushed quartz, limestone filler or fly ash of different fineness. The paper presents all the experimental results as a sort of database and emphasizes the effects on strength of the nature, amount and fineness of mineral admixtures. For short hydration times (1 to 2 days), the nature of mineral admixture is not a significant parameter, as mortars containing the same amount of different kinds of admixtures having equivalent fineness present similar strengths. For long hydration times (up to 6 months), the excess strength due to fly ash pozzolanic activity is quantified by the difference between the strengths of mortars containing the same proportions of inert and pozzolanic admixtures with the same fineness. In the case of inert mineral admixtures, the increase in strength with the fineness of mineral admixtures cannot be explained by the filler effect, but can be attributed to the physical effect of heterogeneous nucleation. In the next part of this work, these results will be used for the elaboration of an empirical model leading to the quantification of both physical and chemical effects. This model presents strong similarities with the previous model based on calorimetric results.

Keywords: Fineness; Mineral admixtures; Supplementary cementing materials; Mortar; Specific surface area; Compressive strength; Fly ash; Limestone filler; Crushed quartz

1. Introduction

This paper presents the third part of an overall project the aim of which is to develop mix design rules for concrete containing different kinds of mineral admixtures. This objective is achieved by the application of a global and phenomenological approach leading to an empirical model that can be used for the evaluation of the physical and chemical effects of mineral admixtures in cementitious materials. The term “global approach” means that physicochemical interpretations of mechanisms and microstructural analyses are intentionally omitted to highlight the empirical relationships between macroscopic properties and the basic characteristics of mineral admixtures.

The different stages of the overall project are recalled in Fig. 1. In the first two parts [1,2], the enhancement effect of inert mineral admixtures on short-term hydration was studied by means of semi-adiabatic calorimetry. In summary, it was shown that this enhancement was due to two antagonistic physical effects: a dilution effect reducing the amount of hydrated cement and a surface effect, related to heterogeneous nucleation, producing an excess of hydrated cement. A decoupling process was suggested for these effects as well as an empirical model, mainly related to the specific surface area of the admixtures, was developed in order to quantify the variation of the degree of hydration induced by the use of inert mineral admixtures. One application of the model coupled with Powers’ law consists of predicting the short-term compressive strength of mortars. The objective of the subsequent parts of this work is to extend the analysis of the effect of inert and pozzolanic

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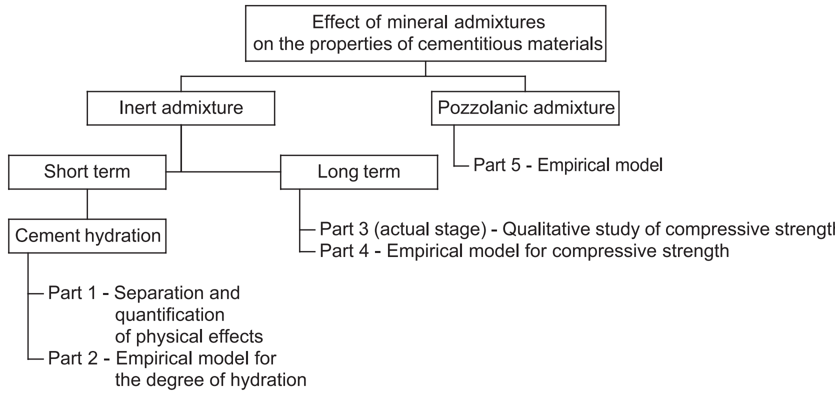

Fig. 1. Phases of the overall project.

mineral admixtures to the short and long-term compressive strength of mortars.

As indicated, this paper presents the third stage of the project, which consists of an experimental study of the influence of type, amount and fineness of inert and pozzolanic mineral admixtures on the compressive strength of mortars up to 6 months. These results will then be used, in the last two parts, in empirical models to quantify the modification of compressive strength of mortars due to physical and pozzolanic effects of mineral powders.

The paper includes:

– the presentation of the results of a large experimental program studying the compressive strength of mortars containing different types, amounts and fineness of mineral admixtures. The results are presented as a database, so as to allow researchers to use them for further investigations and modeling;
– the first-order analysis of the results, including decoupling pozzolanic activity from the overall effect of the mineral admixture.

2. Materials and experimental methods

The binders were standard OPC (Tables 1 and 2), CEM I 42,5R (C1) and CEM I 52,5 (C2) according to French Standard NF P15-301, with specific surfaces (Blaine) of 280 m^2/kg (C1) and 400 m^2/kg (C2). Each cement was received in one batch, mixed and stored in plastic bags until its use in the test program.

Three kinds of mineral admixtures were chosen (Table 2) in order to study a large range of fineness and reactivity (inert to pozzolanic materials):

– Seven finenesses of crushed quartz, identified by their mean diameter in micrometers (μm): Q61, Q35, Q24, Q14, Q11, Q4 and Q2 (Table 2). An angular shape, a density of 2.65 and a crystallized silica content above 99% were a set of common characteristics for all these admixtures. The high crystallized silica content implied that this material was chemically inert, that is, it did not react with hydrated phases of cement at room temperature.
– Three limestone fillers, characterized by an angular shape and a density of 2.70, and also identified by their mean diameter in micrometers (μm): L19, L8 and L3. Limestone is not chemically inert, since it reacts with C_3A and C_4AF to form carboaluminates [3,4]. However, not all researchers agree on the consequences of this reaction on the hydration and compressive strength of cementitious materials [5].
– Two types of raw fly ash (Tables 1 and 2), which can be compared to ASTM Class F fly ash, were identified

Table 1
Chemical and mineralogical compositions of cements (C1 and C2) and fly ash (FAC and FAA)

Oxides	Cement C1 (%)	Cement C2 (%)	Fly ash FAC (%)	Fly ash FAA (%)	Minerals (Bogue)	Cement C1 (%)	Cement C2 (%)
SiO_2	19.8	18.7	52.5	57.3	C_2S	10	10
CaO	63.9	63.0	2.2	1.0	C_3S	61	58
Al_2O_3	4.5	5.5	27.9	24.6	C_3A	7	11
Fe_2O_3	3.2	2.4	5.6	5.0	C_4AF	10	7
MgO	1.1	3.2	1.0	0.6	Gypsum	7	7
Na_2O eq	1.2	0.6	3.7	7.8	Other	5	7
SO_3	3.1	3.0	0.6	0.2			
L.O.I.	0.9	1.4	3.3	5.7			