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Influence of Marble Powder on High Performance Concrete Behavior

A. Talah [1,a] F. Kharchi [2,b] R.Chaid[3,c]*

[1,2]*University of Science and Technology, Built Environment Res. Lab. (LBE), Algiers, Algeria*

[3]*University of Boumerdes, Algeria*

Abstract

This paper reports an experimental study of the influence of marble powder used as partial substitute for Portland cement (PC) on the mechanical properties and durability of high performance concretes. The analysis of the experimental results on concrete at 15% content of marble powder with a fineness modulus of 11500 cm^2/g, in a chloride environment, showed that it contributes positively to the perfection of its mechanical characteristics, its durability with respect to migration of chloride ions and oxygen permeability. On the basis of the experiments performed, it can be concluded that the marble powder is suitable for formulation of high performance concretes (HPC) and their properties are significantly better compared to the reference concrete (RC).

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Keywords: marble powder; durability; high performance concretes.

1. Introduction

The worldwide *demand* for high-performance cement-based materials has increased and predictions are that it will be widely used in construction industry during the early 21st century. Economic and environmental considerations had a crucial role in the supplementary cementing material usage as well as better engineering and performance properties [1-2].In recent years many researches proved that mineral admixtures can be successfully and economically utilized to improve some fresh and hardened concrete properties. Marble powder is produced from processing plants sawing and polishing of marble blocks.

Marble powder is one of the materials which severalty affects the environment and health problems. It is produced from sawing, shaping, and polishing process.

* Corresponding author. Tel.: 213 24 72 24; fax: +213 21 24 79
E-mail address: author@institute.xxx

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Disposal of the marble powder material of the marble industry is one of the environmental problems worldwide today. [3]
Using of marble powder in the concrete has not found adequate attention. Characterization of marble powder used in mortar and concrete were extensively investigated [4].
This study has been exclusively focused on the hardened properties of the high performance concrete containing an optimum quantity of marble powder under aggressive and normal curing regimes. It is now well established that the evaluation of the performance of a concrete mix is not limited to the determination of its mechanical properties since it is of paramount importance to characterize the material in terms of the parameters that rate its durability [5]. The higher the amount of waste marble powder additive, the longer the setting times and the lower strength of the specimens for different curing periods [6].
The effects of using dolomite and waste marble powder as partial replacement of cement on the mechanical properties of concrete were investigated. Test results indicate that the optimized assay of dolomite and waste marble powder as replacement by weight of cement had the best compressive and flexural strengths [7].
Marble powder is an inert material which does not react with cement past. Its addition in small amounts to the concrete mix as partial replacement to cement increases the workability in the fresh state. It facilitates the dispersion of the cement past and the compaction, which causes an appreciable increase in the strength. [8]

2. Materials

The materials used in this investigation were Portland cement, marble powder, aggregate, and water.
Portland cement (CPA-CEM-I / A 42.5) conforming to the Algerian standard NA 443 and marble powder are utilized as cementitious materials. Crushed limestone coarse aggregates with a nominal size of 16 mm, and a specific gravity of 2.70, and natural sand with a specific gravity of 2.60, were used for the concrete samples. The size grain, the fineness modulus (FM = 3.2), the sand equivalent value (SEV= 97%) and shock resistance (SR=33%) show that gravel and sand can be used in developing a high performance concrete (HPC).

3. Formulation, mixtures, specimens and curing procedures

Two formulations of concrete were studied:
- reference concrete (RC);
- high-performance concrete with marble powder (HPCMP);

The prepared specimens were stored for one year in an environment containing 5% calcium chloride, (media 1) and drinking water (media 2).
In order to investigate the marble powder (MP) on the performance properties of concrete, two different concrete mixes were employed, details of which are given in Table 1.The control mix contained only Portland cement as the binder. In the high-performance concrete with MP, Portland cement was partially replaced with, respectively, 15% MP (by weight) obtained by optimisation. All concretes were mixed in accordance with ASTM C192 standard in a power-driven revolving pan mixer. Concrete cubes of 280x70x70 mm in size, and cylinders of dimensions 160Ø x320 mm were cast in steel moulds for the study of the compressive strengths, rapid chloride permeability test, and oxygen permeability test, respectively. All specimens were cast and compacted by a vibrating table. After casting, the moulded specimens were covered with a plastic sheet and left in the casting room for 24 hours. They were then demoulded and divided into two equal groups and cured under the following conditions: in the first curing condition, the specimens were immersed in water until the age of testing, while in the second curing condition, those were immersed in aggressive water (5% $CaCl_2$) until the age of testing. To ensure a concentration of chlorides constant throughout the tests, the solution in the tanks was regularly checked once a week and changed if the difference between the concentration of the solution and the initial concentration exceeded 5%.
The main tests carried out on the fresh concrete are the workability (slump test), the percentage of air contents determined by the aerometer and the density. The results of these tests are given in Table 1.

Table 1.Mixture proportions and properties of concrete

Items	W/C (ratio)	Cement (kg/m³)	MP (kg/m³)	Water (kg/m³)	Sand (kg/m³)	Gravel3/8 (kg/m³)	Gravel8/16 (kg/m³)	Slump (cm)	Air (%)	Density (kg/m³)
RC	0.5	400	0	200	788	163	886	10	2.0	2480
HPCMP	0.5	340	60	200	788	163	886	9	1.7	2510

4. Research methodology

4.1. Compressive strength

To evaluate strength characteristics of each mixture, the compression test was carried out on concrete 160x320 mm cylinder by a 2000 KN capacity testing machine according to ASTM C39. The strength measurements of concrete were performed at 7, 28, 90,180 and 365 days of age. The results reported are the average of nine compression tests.

4.2. Chloride permeability

The resistance of the concrete to the penetration of the chloride ions was measured in terms of charge passed through the concrete in accordance with ASTM C1202.

4.3. Oxygen permeability

The values of oxygen permeability of concretes were measured in terms of flux passed through the concrete in according with our novel experimental method [9]

The design of the test specimen reflects the actual cases where the permeability plays an important role in the durability and security structures, such as a nuclear power plant or storage structures. Fig. 1 shows the general view of testing apparatus employed.

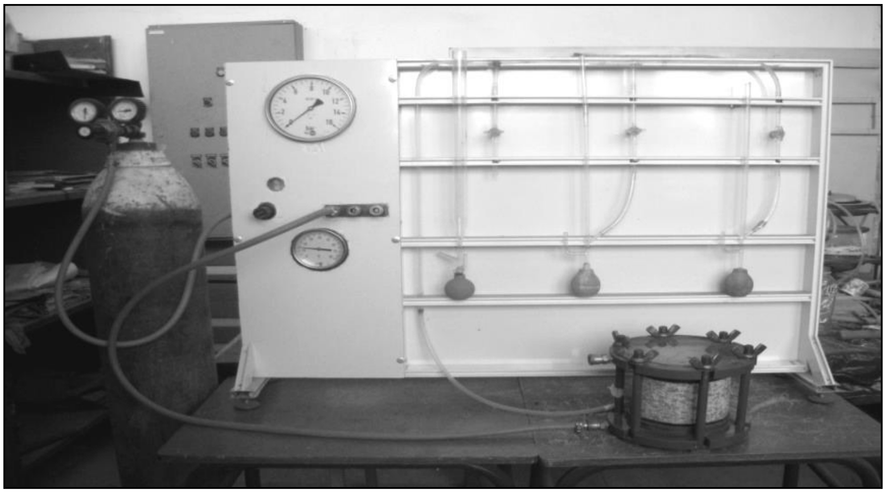

Fig. 1. General view of testing apparatus

5. Results and analysis

The results regarding the compressive strength, chloride permeability and oxygen permeability of the different concretes are graphically depicted in Fig. 2, 3, and 4, respectively.

4.1. Compressive strengths

The data regarding the variation of compressive strength with respect to concrete age and curing condition for different types of concrete in the two mediums are shown in the Fig.2. The strength values for the reference concrete and high-performance concrete with MP ranged from 26 to 48 MPa and from 49 to 65 MPa respectively, depending mainly on MP content, curing condition, and concrete age.
The result indicates that there was a systematic gain in compressive strength with the MP content. It was observed that the ratio of the compressive strength of the specimens subjected to water curing to those cured under aggressive water for the reference concrete deviated up to 29%. However, this ratio for concretes containing MP lay within a range of 3 %, depending mainly on MP content and testing age. This implies that reference concretes are more sensitive to aggressive medium than concrete with MP. Therefore the increase of resistance is remarkable after 28 days, following the nucleation property of this addition.

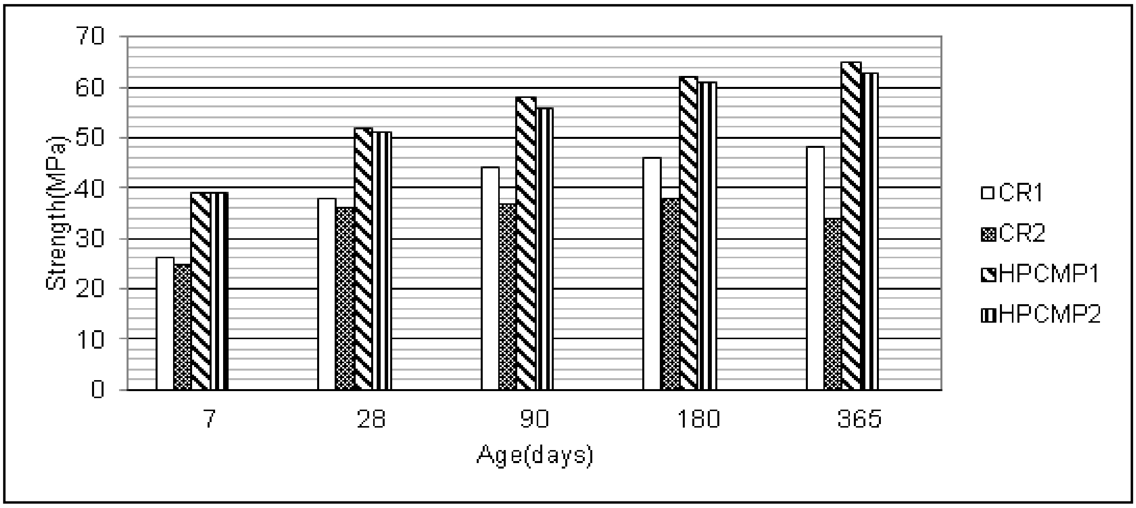

Fig. 2. Evolution of compressive strengths at different ages

4.2. Resistance to chloride ion penetration

The effect of curing conditions (up to 7 and 365 days of age) and the partially replacement of cement with MP(from 15%) on chloride permeability of the concrete is shown inFig.3. The test results show that the values of the electric charge for HPC with MP are too small.
As it is also observed in Fig.3, the extension of the curing period from 7 to 365 days and the curing conditions applied to the test specimens resulted in a reduction of the charge passed through the concretes, with the difference much more marked for the high performance concrete with MP than the reference concretes.
This confirms the contribution of the MP against degradation in a hydrochloric media.

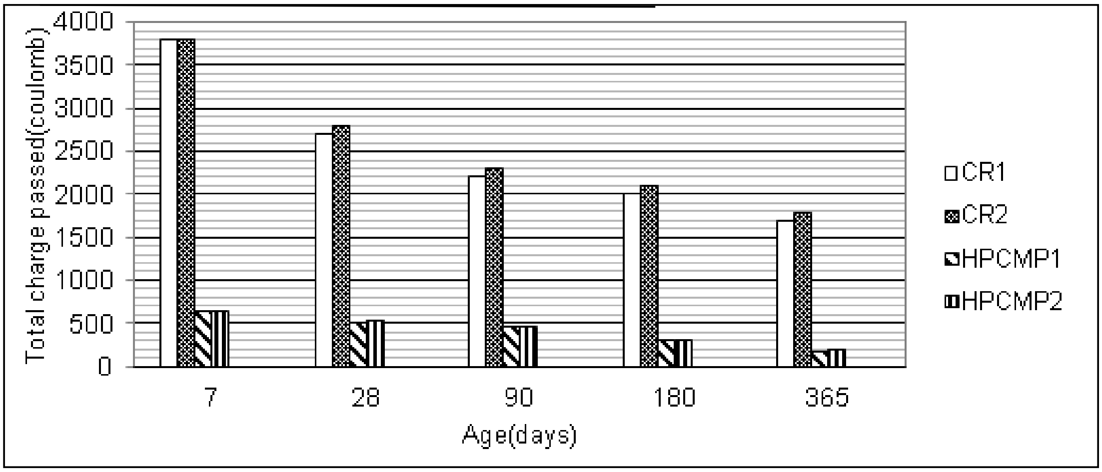

Fig. 3. Variation of charge passed at different ages

5.3. Oxygen permeability

Results presented in figure -4-, show that the apparent permeability tends to decrease when the compressive strength increases, which is the most frequent case.
The incorporation of 15% MP is very advantageous; it allows a reduction in oxygen permeability rate from 85% at the age of one year. It is noticed that (MP) reduced the oxygen permeability during the advancement of age of concrete**.**

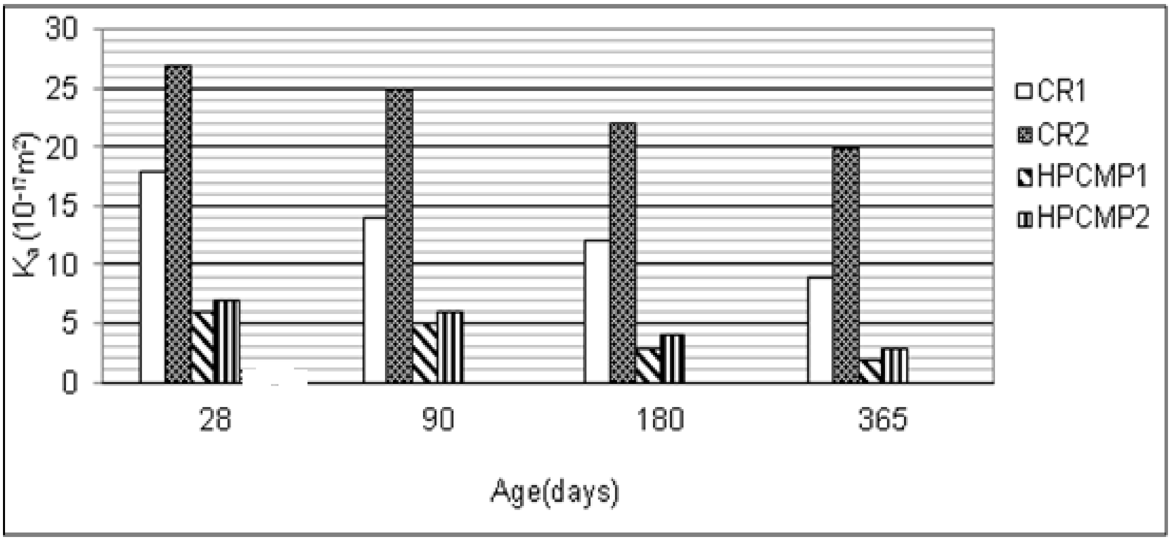

Fig. 4- determination of the apparent oxygen permeability at in inlet 0.3MPa of concrete samples at different ages

6. Conclusions

The following conclusions are drawn from the test results and analysis presented in this paper:
-Marble powder could be used as partial replacement of Portland cement up to 15% in composite cement. Additionally to this, an improvement in durability characteristics is observed; without decreasing the compressive strength of concrete.
-The durability test on the concrete containing MP consisted of immersion in running water, chloride solution, in all cases, structural changes to the samples were noted. In all cases the addition had improved the physical characteristics of concrete relatively to the reference concrete sample.
-Finally, it was noted that additive giving a very power of nucleation and effectively contributes to the reduction of chloride ion penetration and oxygen permeability and increase the durability of concrete. The results show the positive influence of MP on the properties of concrete under hydrochloric mediums.

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