Effect of cementitious additions on mechanical properties of micro concretes

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Abstract

Following needs of concrete market and the economic and ecological needs, several researchers, all over the world, studied the beneficial effect which the incorporation of the mineral additions in Portland cements industry can bring. It was shown that the incorporation of local mineral additions can decrease the consumption of crushing energy of cements, and reduce the CO_2 emission. Siliceous additions, moreover their physical role of filling, play a chemical role pozzolanic. They contribute to improving concrete performances and thus their durability. The abundance of dunes sand and blast furnace slag in Algeria led us to study their effect like cementitious additions.
The objective of this paper is to study the effect of the incorporation of dunes sand and slag, finely ground on mechanical properties of reactive powder concretes containing ternary binders

Key words: Dunes sand, Slag, Minerals additions, Reactive powder concrete, Pouzzolanic reactivity.

1. Introduction

Performances of concretes are mainly related to the densification of the concrete matrix. This is ensured by a judicious choice of cementitious additions. The latter can be natural or industrial waste. Their substitution for cement fulfills as well ecological as economic requirements. This double advantage results in the management and recycling waste which lead to the reduction of cement consumption, and thus CO_2 emission. Reactive powder concretes (RPC) consisted of siliceous fine minerals mixture, are a new generation of concretes. These minerals have pozzolanic reactivity (fixing of lime, resulting from cement hydration in the form of second-generation C-S-H), thus allowing to improve compactness and performances of concretes.
In this investigation we were interested in studying the effect of a binary siliceous addition, locally available, on the mechanical properties of the RPC. This addition is a mixture of blast furnace slag and dunes sand finely ground.

2. Materials used and mixtures tested

Materials used in this study are of local origin, except silica fume imported from Canada which is used for comparison. Physical and chemical properties of these materials are presented in the following tables:

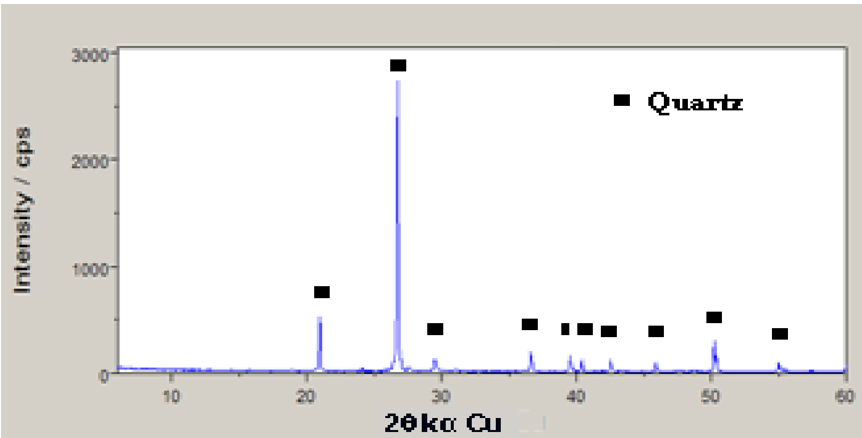
.	Cement	Silica fume (SF)	Ground dunes sand (DS)	Ground slag (S)
Density	3.13	2.20	2.73	3.16
Fineness Blaine(cm^2/g)	3605	/	5000	3230
Fineness B.E.T (cm^2/g)	/	200 000	/	/

Table 1. Physical characteristics of cement and additions used

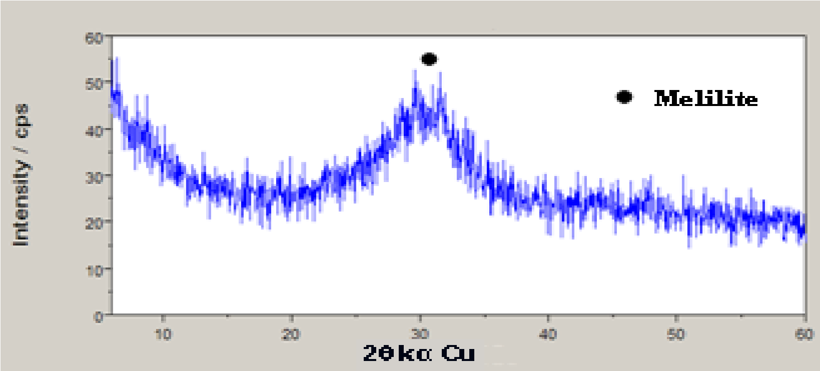
Element	Cement	SF	DS	S
SiO_2	19.35	96.00	94.90	39.59
Al_2O_3	3.5	0.90	1.48	9.73
Fe_2O_3	3.09	0.6	0.48	3.56
CaO	62.31	1.58	0.90	41.23
MgO	1.82	0.2	0.97	3.38
SO_3	1.9	0.45	0.03	0.67
Na_2O	0.16	0.17	0.10	0.01
K_2O	0.59	0.96	0.20	0.58
Cl^-	0.019	/	/	0.007
LOI	5.98	/	/	-1.33
R, Ins	1.59	/	/	/

Table 2. Chemical composition of cement and additions used (% percentages by weight)

a- Ground dunes sand



b- Ground slag



c- Silica fume

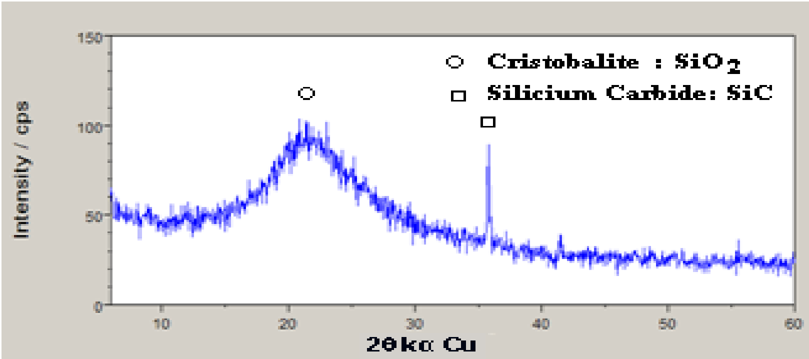


Fig 1: X rays diffraction patterns of additions

Chemical analysis of additions shows that dunes sand and the silica fume, present a high rate of silica compared with the slag. Knowing that the majority of the properties of materials are related to their mineralogy, an X rays analysis has been carried out. It shows that silica fume and ground slag have amorphous structures. Their X rays diffraction patterns are characterized by a centered halation corresponding respectively to the principal line of Melilite for slag, and Cristobalite for silica fume. On the other hand, the ground dunes sand has a crystallized structure of silica Quartz α type.
Concretes tested are containing 15% of binary addition (10+5) %. The various compositions tested are presented in the following table:

	RPC control	RPC 1	RPC 2	RPC 3	RPC 4	RPC 5	RPC 6
C	882	750	750	750	750	750	750
SF	-	88	44	88	44	-	-
DS	-	44	88	-	-	88	44
Slag	-	-	-	44	88	44	88
Sand	1235	1235	1235	1235	1235	1235	1235
SP*	16	16	16	16	16	16	16
W	212	212	212	212	212	212	212
W/B	0.24	0.24	0.24	0.24	0.24	0.24	0.24

**SP: Super plastisizer*

Table 3. Concrete mixes tested (Kg)

3. Experimentation and results

The compressive strength test enabled us to determine the activity index (IA), by using the following expression:

$$\mathbf{IA = 100 \times \sigma_c / \sigma_{cont}}$$

with:

σc: Compressive strength of concrete with additions

σ_{cont}: Compressive strength of control concrete (without additions)

	3 days	7 days	14 days	28 days	90 days
RPC Control	100	100	100	100	100
RPC 1	85	101	105	104.5	118
RPC 2	88	98	100	99	97
RPC 3	88	99.4	104	105	107
RPC 4	88.5	107	103.4	104	105
RPC 5	91.4	90.3	95.7	96	97.3
RPC6	89.6	100	99	97.5	100.3

Table 4. Activity index of different RPC

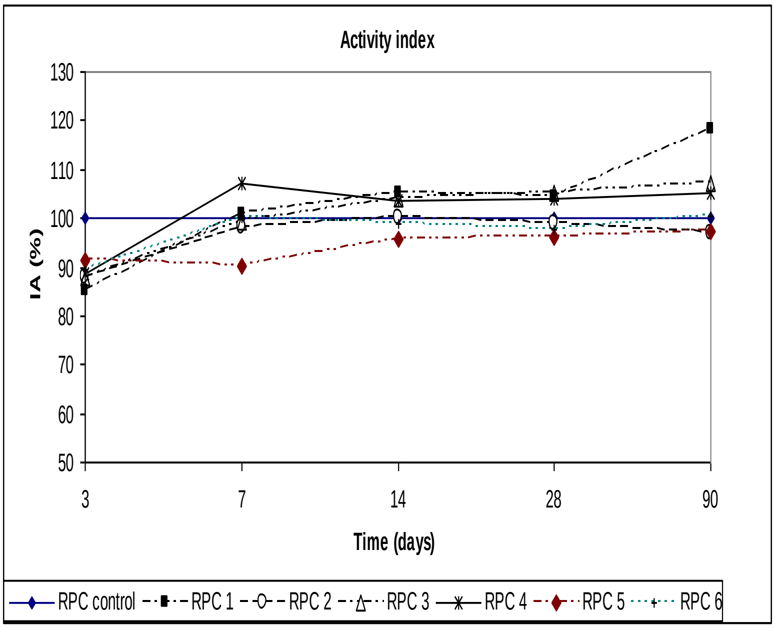


Fig 2: Activity index of different RPC tested

A. At early ages (T ≤ 14 days)

Compressive strengths of RPC with additions are lower than that of the control. This is due to the introduction of additions by substitution and their pozzolanic reactions which did not take place yet.

From the 7th day, concretes containing a high proportion of amorphous addition (RPC1, 3,4 and 6) have similar strengths to that of the control. This shows that the pozzolanic reaction of amorphous additions started at this age.

Concretes containing 10% of SF (RPC 1 and RPC 3) have similar strengths and largely higher than that of the control. Silica fume has a strong pozzolanic reactivity considering its very high fineness and its amorphous structure. The effect of the 2nd addition (DS or slag) is not detectable at early ages, since it is used in low proportion (5%).

Concrete RPC 6 (with 10 % of slag) presents similar strengths to those of the control, which are slightly higher than that of the RPC 5 (with 10% of DS). This explains that the slag, although its low content of SiO_2, is more reactive than the DS at early age.
These results show that the kinetic of pozzolanic reactivity of additions at early ages is influenced much more by its morphology and than its fineness. This result is in agreement with the literature. Amorphous materials are more reactive at early ages than crystalline materials.

B. At advanced ages (T > 14 days)

- *Reactivity of slag:*

Concrete RPC 6 presents similar strengths to those of the control, which are slightly higher than those of the RPC5. This is explained by fixing an important amount of lime with 10% of slag than with 10 % of DS.

- *Reactivity of dunes sand:*

Strengths of the concrete RPC 1 are higher than those of the control and the BPR3. This is attributed to the presence of 5% of DS in the RPC 1.

According to these results, it has been showed that dunes sand is introduced with a low proportion (5%), and in the presence of an amorphous addition led to an improvement of properties of concretes at long-term. This is due to its high content of silica and its high fineness, translating the pozzolanic reactivity of SD.
The concrete based on binary addition (10% slag +5% SD) has same strengths as those of the control. It represents the economic composition and answers the double economic and ecological advantages.

4. Conclusion

The morphology of the addition has a great influence on the pozzolanic reactivity: amorphous additions have a strong pozzolanic reactivity at early ages. Silica fume has a strong pozzolanic reactivity considering its very high fineness and its vitreous state. The amorphous structure make the ground slag reactive at early ages , but its low silica content influences its long-term pozzolanic reactivity.
The ground dune sands, although its crystalline state, becomes reactive at long-term, when it is added with 10% of amorphous addition.
The concrete based on binary addition (10%laitier +5%SD), is the most economic composition. It has the same strengths as those of the control. Moreover, it answers the double economic and ecological advantages, which is translated by the reduction of cement consumption and a reduction in the CO_2 emission.

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