ENHANCING VALUE OF DAM DREDGED SEDIMENTS AS A COMPONENT OF A SELF COMPACTING CONCRETE

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Abstract, This experimental work is a part of a long research on the valorization of the dam dredged sediments issued from Fergoug Dam (Mascara-West Algeria). These sediments have to be subjected to thermal treatment to become reactive with the cement and thus to obtain an artificial pozzolana. It is therefore a question of developing the calcined mud as substitutable material in part to the cement used in the composition of self compacting concrete. The objective of the present work is to highlight its influence on the behavior of self compacting concrete compared to that of the natural pozzolana and this, in fresh and hardened states.
The study is being conducted on three SCC, the first using 20% in volume of natural pozzolana, the second with 20 % of calcined mud and the third for the sake of comparison is made with cement only.
The first results showed the possibility of obtaining SCC with calcined mud complying with the AFGC recommendations (AFGC, 2000), having a good mechanical behavior which makes interesting its development as construction materials.
Keywords : valorization, sediments, mud, dam, self compacting concrete, fresh state, hardened state.

1 Introduction

The specificity of SCC, led to the use of the quantities of fines (cement+additions) in the concrete at an average of 500 kg/m^3. To adapt to the growth of the market, the cement sector oriented its technological developments toward solutions that allows either to improve the performance of the manufacture of building materials or to reduce their cost of production. The building materials sector (large consumer of energy) seeks to optimize its energy costs; thus it is moving more and more to the use of mineral additions whose cost of production is lower than that of the cement, and therefore can partially replace it.

Another reason is induced by the evolution of the Algerian policy toward the protection of the environment. The erosion causes environmental problems and among its immediate consequences: sedimentation and reduction of the capacity of the dams. The quantity of sediments deposited in 2011 is of 970 hm^3, either a rate of bridging of 12% of the total capacity of 6814 hm^3 (ANBT, 2011) (Fig.1). Therefore to eliminate these sediments, the dredging remains the effective solution.

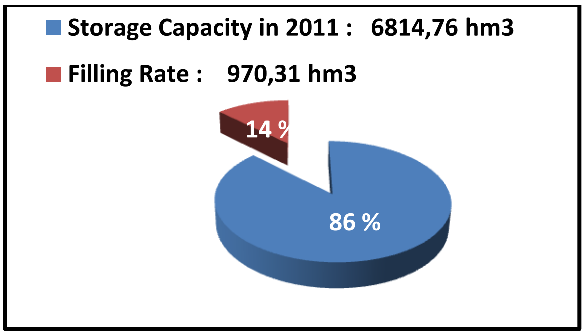

Fig. 1. The rate of filling relative to the total capacity of Algerian dams

The rate of silting is about 52.94 hm^3 a year, the dams wich have high rates are Tchy-Haf located in Bejaïa (center of Algeria), followed by Gargar dam in Relizane (west of Algeria) and Beni Amrane dam in Boumerdes (center of the country) etc ... (Fig. 2).

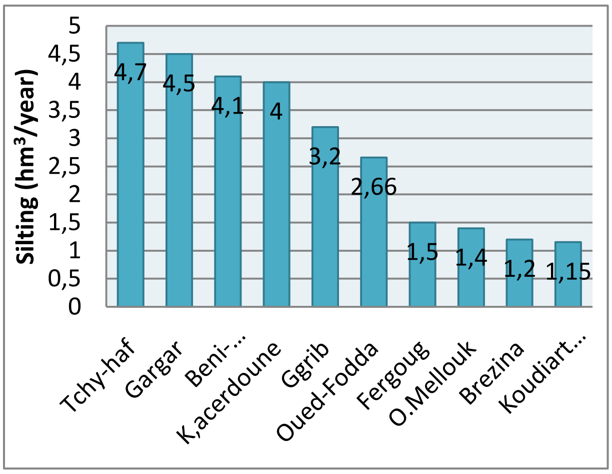

Fig. 2. Silting/year of Algeriens dams

In this context, the introduction of the dredged sediments of dams that must be calcined to become reactive with cement seems to be an advantage. The chemical reactions which are developed during the manufacture of cement, release carbon dioxide (CO_2) thus contributing to the increase of the greenhouse effect whereas the mineralogical transformations of the mud generate only water vapor. Indeed, the mud does not compete with the cement but It completes and improves the cement more than replaces it. The benefits of partial substitution of the cement with pozzolanic materials are various: increase of the strength against chemical attack, impermeability and durability of the mortar, reduction of alkaline reactions with the aggregates (Bessa et al., 2004) (Bich, 2005).

The present work aim to contribute to the development of dam dredged sediment subjected to a thermal process (calcination), as artificial pozzolanas usable in the self compacting concrete.

2 Materials and methods

2.1 Materials

2.1.1 Cement

The cement used is a CPA CEMI 42.5 ES (Selenide waters). Its specific Blaine surface is 3180 cm^2/g. The mineralogical composition is given in **Table 1**.

Table 1: Mineralogical Composition (%) of cement

C_3S	C_2S	C_3A	C_4AF	CaO libre	Gypsum
53.13	23.55	6.76	12.13	< 01	2.7

2.1.2 Mud (dredged sediments)

All the quantity of mud is taken from the discharge area downstream of the dam. It has a specific surface Blaine equal to 6740 cm^2/g.

It was prepared an artificial pozzolana after a thermal treatment according to the following steps:

- After drying in a drying chamber at 105 °C, the sediments were crushed and sieved by dry way. The passing which go through 80 µm and which represent more than 95% of the removal are recovered for cooking.
- the operations of calcination required some care to avoid thermal shocks, the cooking rate was then regulated to 5°C per minute and the calcination temperature of 750°C was maintained constant for 5 hours (Semcha, 2006).
- The product thus obtained (calcined mud) has been kept away from air and moisture.

Figure 3 shows the steps in preparation of the mud.

Fig. 3. Steps of preparation of the mud

2.1.3 Pozzolana

The pozzolana used is a natural pozzolana with a specific surface Blaine equal to 4453 cm^2/g.
It is supplied in the form of crushed rock type of pumice stone and slag of diameters variants of 5 to 10 mm in order to substitute it to the cement. We first proceeded to its drying at 105 °C in order to eliminate any potential moisture and facilitate its grinding; it is then completely crushed and then passed through sieves. The whole passing through sieve 0.08 mm is retrieved and used as an alternative to the cement with different proportions.

The chemical characteristics of the two additions are given in **Table 2**.

Table 2 : Chemical Composition of additions (%)

Element	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO3	K_2O	Na_2O	PF
Calcined mud	51.69	15.49	7.53	18.06	3.08	0.23	2.99	0.41	1.87
Pozzolana	42.96	16.32	8.41	9.72	4.57	0.11	1.59	0.47	4.85

2.1.4 Aggregates

The aggregates used in this study are of limestone (sand and gravel (0/4, 3/8 and 8/15).

2.1.5 Superplasticiser

One additive has been used in the SCCs, it is a superplasticiser high water reducing and limiting the segregation, with unit weight of 1.06 and 30.2 % of dry extract.

2.1.6 .Concrete mixes

The table 3 gives the compositions of the three formulations of the SCC. The first mix using 20 % in volume of mud (SCC_S), the second 20% in volume of natural pozzolana (SCC_P) and the last one is a reference mix (SCC_C) without additions. Their different characteristics are given in **Tables 3** and **4**.

Table 3 : Components of the SCC

Components (Kg/m^3)	SCC_C	SCC_M	SCC_P
Cement	448.16	407.96	410.23
Mud	/	81.59	/
Pozzolana	/	/	82.05
Water	224.08	203.98	205.12
Superplasticiser	8.20	10.61	9.64
Sea Sand	560	560	560
Crushing Sand	251	251	251
Gravel 3/8	333	333	333
Gravel 8/15	499	499	499

With:
SCC_C : Reference Self compacting Concrete without additions
SCC_M : SCC with 20% of mud
SCC_P : SCC with 20% of natural pozzolana

Table 4 *:* Characteristics of concrete mixes

Characteristics	SCC_C	SCC_M	SCC_P
W/C	0.5	0.5	0.5
Additions /Cement(%)	-	20	20
Sp/C (%)	1.83	2.60	2.35
Volume of paste (l/m^3)	375	375	375
G/S	1.02	1.02	1.02
Volume of granular skeleton (l/m^3)	625	625	625

2.2 Methods

2.2.1. Fresh state tests

Before defining a SCC, it must be ensured that the properties comply with the AFGC recommendations [1] by the following specific tests.

✓ Slump flow test

In the slump flow test, freshly mixed concrete is removed from a standardized DIN cone (**Fig. 4**). The SCC forms a spread with a diameter ranging between 60 and 75 cm.

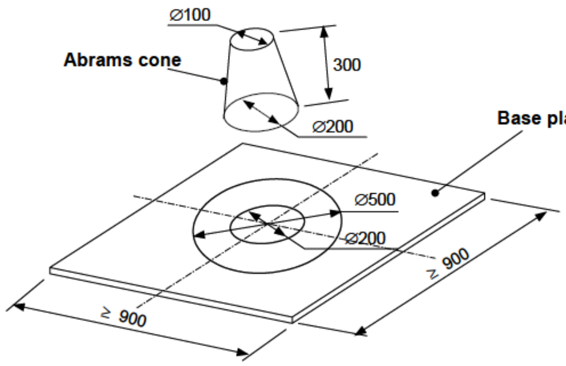

Fig. 4. Parameters of slump flow test

✓ L. Box test

The L-Box test evaluates concrete flow in confined surroundings and helps to verify that the flow will not be blocked by any obstructions. Heights H_1 and H_2 are measured and the result is expressed in term of the filling ratio H_2/H_1 (**Fig. 5**).

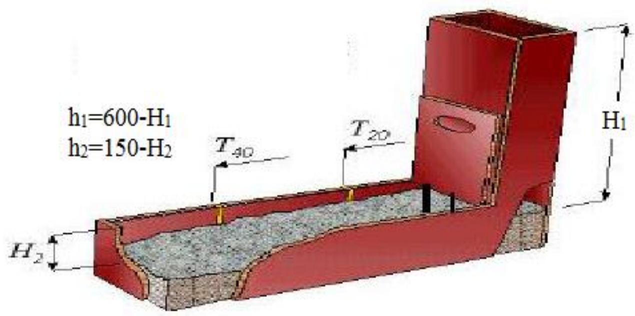

Fig. 5 : Parameters of L-Box test

✓ J-Ring test

The test of J-Ring allows to provide information on the restricted deformability, and the homogeneity of the mixture.

The principle of the test is to place the slump test in the center of the metal plate surrounded by the J- ring (**Fig. 6**), then to fill it with a representative quantity of concrete, the cone is then raised to measure the spreading out as well as the heights of concretes located at the center of the plate (***h1***), inside (***hai***) before the bars and outside (***hri***) after the bars of the J-ring.

Next, the heights h_m and h_r are determined to fulfill the condition $2h_r - h_m < 15$ mm.

Such as :

$h_m = \Sigma\,(h1 - hai)\,/4$

$h_r = \Sigma\,(hai - hri)\,/4$

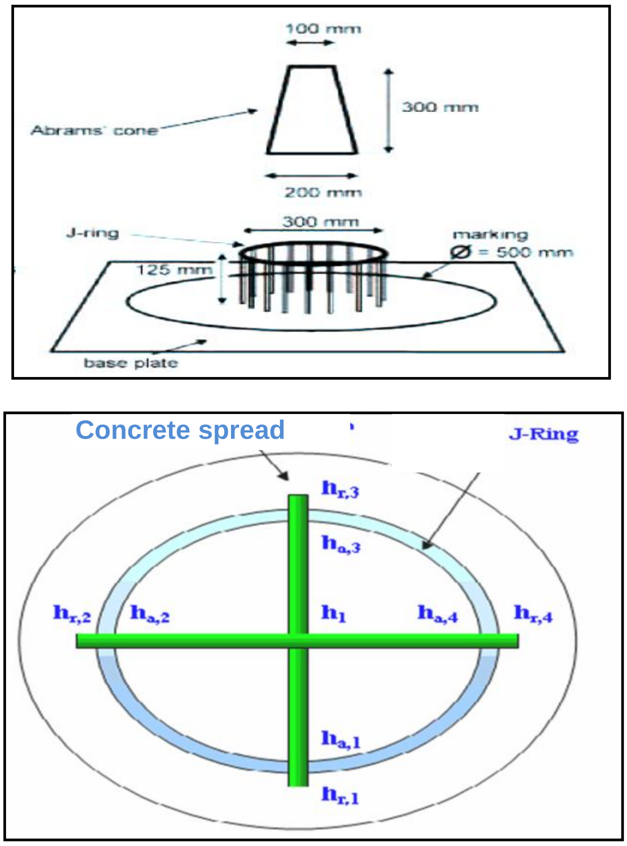

Figure 6 : Parameters of J-Ring

✓ Sieve stability test

This test measures the proportion of fine elements in concrete (laitance) passing through a 5 mm diameter sieve. It helps to determinate the risk of segregation and the degree of concrete stability. To determine the acceptability of the mix, three classes are defined:

- 0% $< \pi_{laitance} <$ 15% good stability
- 15% $< \pi_{laitance} <$ 30% critical stability
- $\pi_{laitance} >$ 30% bad stability (segregation, unusable concrete)

$\pi_{laitance}$ is the ratio of the weight of laitance and the weight of sample concrete.

✓ Bleeding test

The aim of this test is to measure the quantity of liquid that rises to the surface of a 15X30 cm^2 test specimen after three hours. Significant degree of bleeding, reduces the esthetic quality of concrete facings and affect the durability of components. The bleeding value must be less or equal to 3‰ in volume.

2.2.2. Hardened state tests (compressive strength)

To measure the compressive strentgh according to the NF P 18-406 standard, cubic specimens (7x7x7) cm^3 have been maintained in thermohygrometriques conditions (T = 20±2 °C, HR= (55±5 %). The breaking tests were performed at 3, 7, 14 28, 60 ,90 and 150 days.

3 Results and discussion

3.1 Fresh concrete state

The results of the characterization tests of the three SCC manufactured in the fresh state are given in **Table 5**.

Table 5 : The results of characterization tests in the fresh state

Concrete Test		SCC_C	SCC_M	SCC_P
Slump flow	Ø (cm)	70	68	68
	T50 (s)	3.56	3.83	3.69
L- Box	H2/h1 (%)	89	83	86
	T20	2.39	2.58	2.41
	T40	3.76	3.98	3.80
J-Ring	Ø (cm)	62	58	59
	2Hr (cm)	0.73	0.69	0.69
	HM(cm)	0.54	0.51	0.50
	2Hr-hm (cm)	0.92	0.87	0.88
Sieve stability	%	6.91	5.11 .	5.87
Bleeding	‰	1.21	1	1.09

3.1.1 Slump flow test

Table 5 shows that the three SCC tested meet the condition of spread diameter given by the AFGC recommendation [1] (60 cm) ≤ Ø ≤ 75 cm) [1] (**Fig. 7**).

The spread diameters obtained (70 cm for the SCC_C and 68 cm for the SCC_M and SCC_P) classify these mixes as self compacting concretes in an unconfined environment.

The values of t50 (the time that takes the concrete to obtain a spread diameter of 50 cm) are consistent with the most common characteristics of a SCC in the fresh state (3s≤t50≤ 5s) [1].

For the three SCC formulations, the aureole laitance on the concrete boundary are absent. Moreover, the coarse aggregates were always involved correctly by the cementing matrix and did not remain accumulated in the concrete medium.

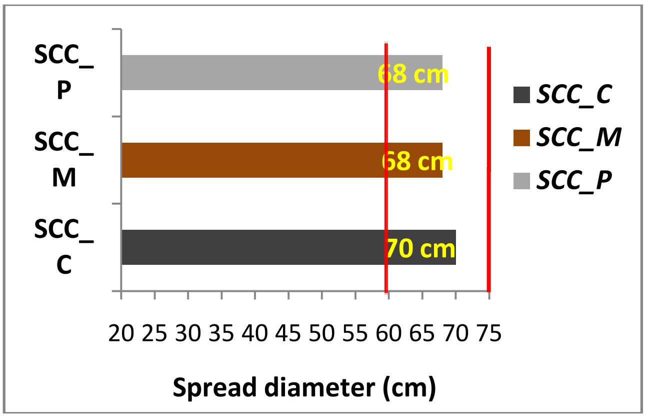

Fig. 7. Results of slump flow test

3.1.2 L- Box test

The dynamic segregation of the three SCC is characterized by the L-Box test. The three formulations show a filling rate greater than 80% (**Fig. 8**). Therefore, these concretes have good mobility in a confined environment that in spite of the reinforcements which make obstacle.

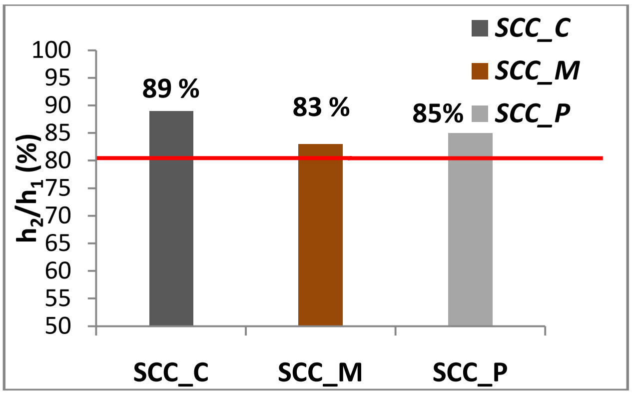

Fig. 8. The results of L-Box test

3.1.3 J-Ring test

The three SCC present no lock through the frames and satisfy the condition of the test (**Fig. 9**).

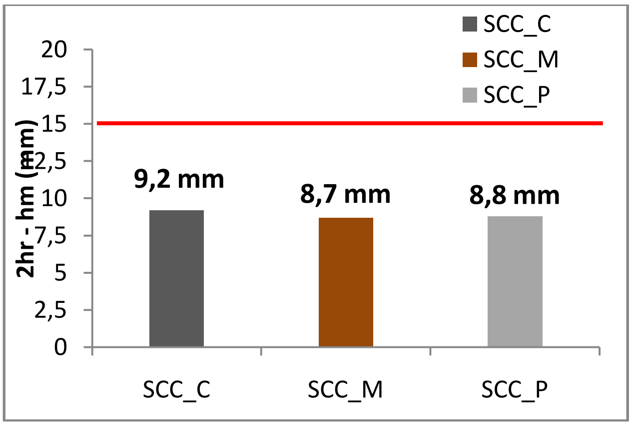

Fig. 9. The results of J-Ring test

3.1.4 Sieve stability test

The results obtained from tests of sieve stability show that the three compositions tested have a good stability ($0 \leq \Pi \leq 15$ %) (**Fig. 10**).

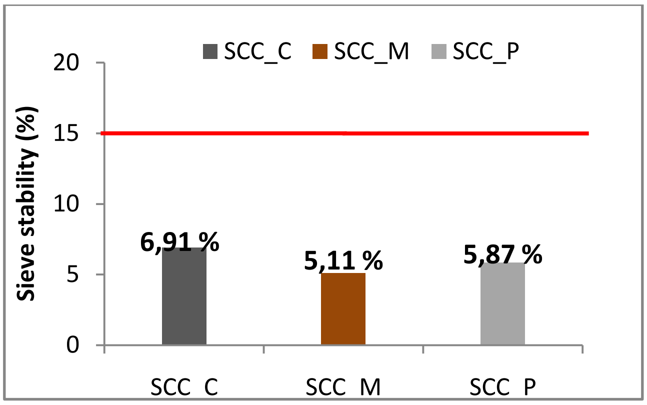

Fig. 10. The results of sieve stability test

3.1.5 Bleeding test

All the concretes comply with the condition of this test whose value must be less or equal to 3‰ in volume (**Fig. 11**).

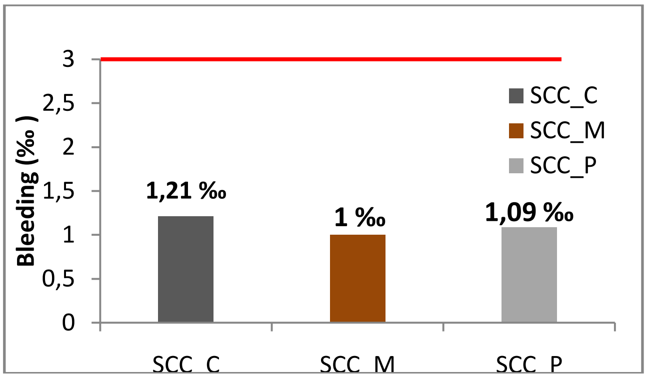

Fig. 11. The results of bleeding test

3.2 Compressive strength

The compressive strength is an essential characteristic of concretes and one of the basic parameter of this study. It was measured at different maturities and represents the average of the breaking values of three specimens (7x7x7) cm^3. The results are shown in **Fig. 12**.

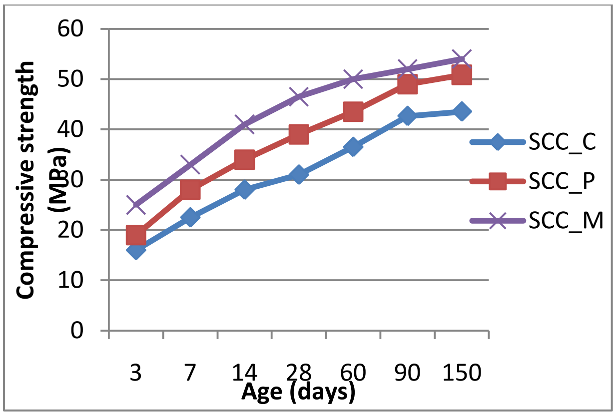

Fig. 12. Evolution of compressive strength of SCC

According to the results, it is noted that the compressive strength of all SCC tested increases regularly with the age and show no fall. The SCC_M with calcined mud presents the higher strength (46.5 MPa at 28 days) compared to the SCC_P with natural pozzolana and the reference concrete (SCC_C).

In fact, the SCC_M and SCC_P have a superiority in the development of mechanical performance in relation to the reference mix respectively in the order of 36 %, 16% in 3 days and 33 %, 21% in 28 days.

Beyond this age and up to 150 days the compressive strengths of the SCC incorporating the mud and the pozzolana continue their ascents with an increase in strength when compared with the reference mix SCC_C of approximately 19% and 14% respectively. This can be attributed to the pozzolanic activity of the additions which is slow at the young age and which is growing lately.

The incorporation of the mud in self compacting concrete mix generates an acceleration of its mechanical strength to all the ages. The particles of this addition when they are well deflocculated by the superplasticiser, 3. promote hydration of the cement and the mud, mainly by a physical effect and lead to a matrix mix whose structure is more dense all the more that the mud has a higher fineness (Belguesmia, 2011). These effects have a visible influence on the mechanical properties.

4. Conclusion

The tests for the characterisation of SCC in the fresh state have shown that they respect the specifications of the AFGC. The additions used can have both beneficial effects on the SCC costs by the improvement of the fluidity and the elimination of the risks of segregation in relationship with the dosage of superplasticiser, that on the BAP hardened by the improvement of mechanical behaviors;

The substitution of the cement with a quantity of additions (SCC_M and SCC_P) causes a significant increase in the compressive strength up to 150 days of hardening.

The outcome of the dam silt improves the compressive strength in the long term because its pouzzolanicity gives birth to a second C-S-H, which improves the filling of the pores and therefore increases the mechanical properties [5].

However, in comparing the two additions, the burned silt to a direct impact and more pronounced on the mechanical behaviour. The metering in superplasticiser used for this SCC may also have its positive impact, given that it is much more important.

These results clearly demonstrate the interest of developing the dam dredged sediments. This investigation can be developed further by a durability study, as new parameters were considered to make substitute for several cement proportionings by the calcined mud and to study the optimal and/or maximum percentage of substitution that controls the behavior of the SCC towards chemical attacks.

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