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Formulation and characterization of self compacting concrete with silica fume

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Self-compacting concrete (SCC) was elaborated using local materials and silica fume (SF) as admixture in 15% of cement quantity, two different Portland cements (PC) and two different superplasticizer that the chemical nature is polycarboxylate and plynaphtalene, the aggregates used are (AG 3/8 mm, AG 8/15 mm), coarse and fine sand (SC, SF) witch fineness modulus 3.2 and 1 in the order. The dosage of the different superplasticizer used is chosen after experimental spreading tests of each self compacting concrete formulation. Results of fresh concrete tests executed, as L-box and segregation resistance are on concordance whit values recommended by the French association of civil engendering. Also the mechanical characterization was conducted by compressive strength and splitting compression testing procedure, results values are in the range higher than 20 Mpa at the seven day by the compressive test for the all compositions, and the highest value was 40.93 MPa at the 28 day bay compressive test of the fourth's formulation specimens, the values of splitting compressive tests of al formulation specimens at 7, 14 and 28 days, was situated between 2.01 and 4.40 MPa. In order to determine the superplasticizer saturation assay in of cement pasts used in self compacting concrete, the stady was completed by a rheological stady with a variable velocity gradient, so as to estimate the quantity of saturation assay of superplasticizer and the formulation, also the flow models of cement paste.

Key words: Self-compacting concrete (SCC), silica fume, rheology, stress.

INTRODUCTION

Self-compacting concrete (SCC) have high fluidity; their implementation that allows concrete to be placed in complicate forms without any strain vibration and prohibit segregation. Superplasticizers and other additives are used production of SCC; superplasticizers impact high fluidity and prevent segregation, the additions of fillers reduce the quantity of superplasticizers used in SCC mixes, compared to normal concrete (Yahia et al., 1999). Also, the use of self-compacting concrete in construction reduces the achievement time at 40% compared to normal concrete (Perssoiv et al., 1998; Nocher, 2001).

Silica fume (SF) is one of several types of industrial byproducts generated. With increased environmental awareness which is a byproduct of the smelting process in the silicon and ferrosilicon industry. Silica fume is very effective in the design and development of high strength high performance concrete (Rafat, 2011).

The addition of fillers and the replacement of cement in SCC participate to reduce the gas emissions, in cement production Malhotra and Mehta (2002). Miura et al. (1993)

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studied the effect of replacing 30% of cement by fly ash in concrete, they concluded at the amelioration of fluidity and workability of concrete, also Bouzoubaa and Lachemi (2001) in their work replaced 50% of the cement used for the formulation of SCC, the result in compressive test was 35 Mpa at 28 days.

Silica fume is used at a dosage corresponding between 5 and 10% of the total weight of cementitious materials (Steven et al., 2004). The silica fume is used in a high level impermeability application required and the high strength concrete. When the concrete is exposed to deicing salts, the maximum amount of silica fume should be at 10% of the mass of cementitious materials, (Steven et al., 2004). The addition of silica fume is very advantageous, addition of 5, 10 and 15% of silica fume cement supply, allows a reduction of the phenomenon of swelling of 121% to 16 day trial. In others papers we found the variation of the dosage of silica fume used in SCC from 0 to 20% (Raharjo et al., 2013).

The rheology of cement pastes was studied bay (Zhang and Han (2000) they conclude that the adding of mineral mixtures in cement pastes decrease the viscosity and the elastic strain limit compared to the pastes without additions. Zhang et al. (2000) and Park et al. (2005) noted that the adding of silica fume in paste cement decrease the viscosity and elastic stress limit. The variation of the dosage on silica fume from 10 inutile 25% in paste cement, with fixed superplasticizers at 3%, produces a small increase of shear stress (Cyr et al., 2000).

The investigation conducted by Salem et al. (2002) on the effect of adding silica fume for 10, 20 and 50%, with a (W / C) ratio = 0.6, concluded at hysteresis effect, which explains the thixotropic behavior of cement pastes.

The objective of this work is the formulation of a self-compacting concrete with local materials with the addition of silica fume, and the study of the rheological behavior of fresh SCC mix.

MATERIALS AND METHODS

Aggregates

In this part of the work, physical and mechanical characterization of local aggregates used was determined, with previous correction of the sand which was levy from the river of Baghlia (Boumerdes, North of Algeria), with fineness modulus Mf = 3.2. It was considered as rude sand and correction done by fine sand in which a fineness modulus is f = 1, resulting from BOUSSAADA (South of Algeria). Sand corrected by the Abrams formula, the fineness of sand corrected is Mf = 2.72.

Characteristics of materials

Table 1 summarizes the characteristics of the aggregates used in this work.

SCC mix proportions

In this work, the calculation of mix proportions for SCC was done using the Japanese method. The specifications of this method are as follows (Philippe, 2004).

(i) The volume of gravel is fixed according to the AG / S; ration (Agregate/Sand) is close to 1.
(ii) The volume of the dough is made between 330 and 350 kg/m^3.
(iii) The weight of the cement varies from 300 to 400 kg/m^3.
(iv) The mass additions up to 200 kg/m^3.
(v) For the superplasticizer dosage close to the saturation dosage is recommended.

Superplasticizers

Superplasticizers used in this work are polycarboxylate (Medaflow 30), which is high range reducing water; it is called the third superplasticizer generation, and polynaphthalene (Medaplast SP 40); a high range water reducing superplasticizer type polynaphthalene sulfone (PNS), to obtain concrete and mortars of high quality. It comes from the Granitex company, a packaging company and distributor of various adjuvants used in construction in Algeria.

Silica fume

Silica fume is an industrial product in the form of very fine powder, with a SiO_2 content of over 90 and 3% in loss on ignition.

Self-compacting concrete formulation

SCC formulation is performed according to the Japanese method. We set the G / S 0.9, the cement is 400 k/m^3, the ratio (W / C + F) is set at 0.42, the mass of the silica fume is 15% of the weight of the cement.

Stock volume is calculated by the following formula:

The cement paste = cement + water + addition (silica fume) + superplasticizer.

Therefore the total volume of the cement paste is the sum of the volumes of these constituents.

(i) Volume of cement: 400/3.1 = 129.03 L;
(ii) Volume of silica fume: 60/2.25 = 26.66 L;
(iii) The volume of water: E / (C + SF) = 0.42 then E = 193.2 L;
(iv) The volume of dry aggregates: 1000 - the volume of the cement paste;
(v) The volume of superplasticizer dosage is determined according to its saturation obtained by averaging the test to Abrams cone.

Table 2 summarizes the amounts of the four volume formulations BAP.

Characterization of self-compacting concrete

Fresh concrete

After making concrete, we went to his characterization fresh. We used to test the box L, a box that we made to the dimensions specified in the theory.

The results obtained during tests on fresh concrete as follows: L box testing, sieve stability and spreading the Abrams cone are shown in the Table 3.

The results obtained during tests in L-box (Figure 1 are higher than 80% (Table 3), this is due to the fluidity of different SCC. And segregation resistance testing sieve, give results lower than 15% (Table 3). Values and spreading the Abrams cone is between (650

Table 1. Physical and mechanical properties of materials.

Aggregates 3/8	Aggregates 8/15
Density 1400 kg/m^3	1400 kg/m^3
Density 2620 kg/m^3	2620 kg/m^3
Los Angeles 26%	25%
Micro Deval 17%	15%
Sand Fineness modulus (fM)	
fM sand Baghlia*	2
fM sand BOUSSAADA*	1
fM sand corrected	2.78

*Aggregates quarry in Algeria.

Table 2. Quantity (kg) of the components in each formulation.

Formulation Code	Cement	Water	Silica fume	Aggregate 3/8 (mm)	Aggregate 8/15 (mm)	Coarse sand	Fine sand	Superplasticizer SP
F I	400	193.2	60	533.14	265.04	582.92	243.78	7.2
F II	400	193.2	60	534.27	264	582.41	241.66	8.0
F III	400	193	60	534.08	264.99	584.64	242.55	6
F IV	400	193.1	60	534.27	264	243.69	241.46	8.0

Table 3. Test on fresh concrete.

Formulation Code	L-Box	Segregation resistance (%)	Staggering test (cm)
F I	0.81	3	68
F II	0.84	5	71
F III	0.82	7	67
F IV	0.86	6	67.5

Figure 1. L-Box.

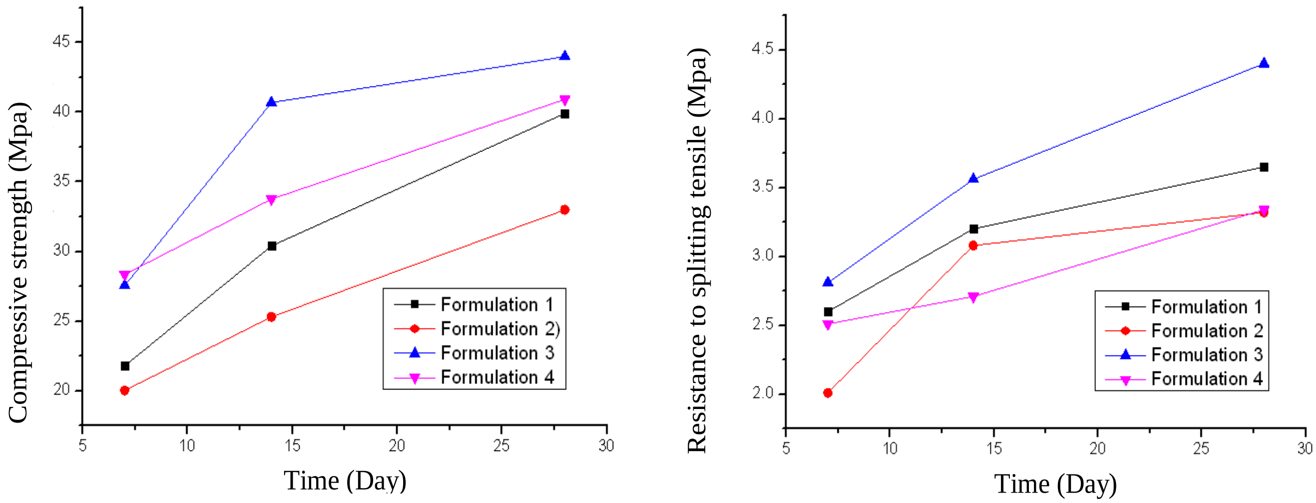

Figure 2. Evolution of mechanical strength in tension and compression.

Figure 3. Concrete specimen.

and 750 mm) (Table 3), in summary, all these values are within the range recommended by the AFGC to obtain a SCC.

Characterization of SCC hardened state

Developed cylindrical specimens were tested in compression and splitting tensile, as shown in histograms (Figure 2).

RESULTS

The results of fresh properties of all SCC mixtures are included in (Table 3), as seen all SCC mixtures exhibited satisfactory slump flows in the range 650 and 750 mm, which is an indication of a good deformability. In addition L-box test is more sensitive to blocking. There is a risk of blocking of the mixture when the L-box blocking ratio is below 0.8. Blocking ratio of SCC produced with all formulations is also given in Table 3. Blocking ratio (h_2/h_1) must be between 0.8 and 1.00. Maximum L-box test and all the mixtures of SCC have remained in target range which is as per EFNARC standards. Also the percentages of milt obtained by segregation resistance testing on sieve can be explained by the absence of segregation, due to the viscosity of the paste that stops separation of aggregates from the past.

The hardened properties that were stated for all the mixtures were the compressive strength and splitting tensile of SCC specimens (Figure 3) of each formulation. It can be seen from Figure 2 that the compressive strength values are in the range of 20 to 26 MPa at 7

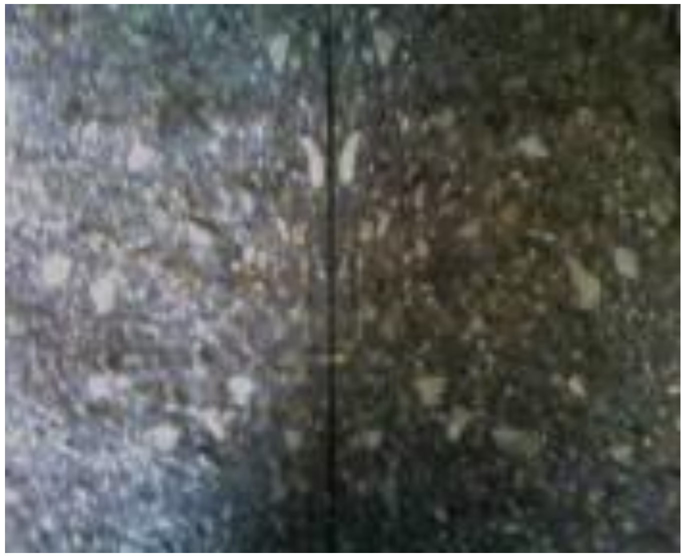

Figure 4. Area of specimen after splitting test.

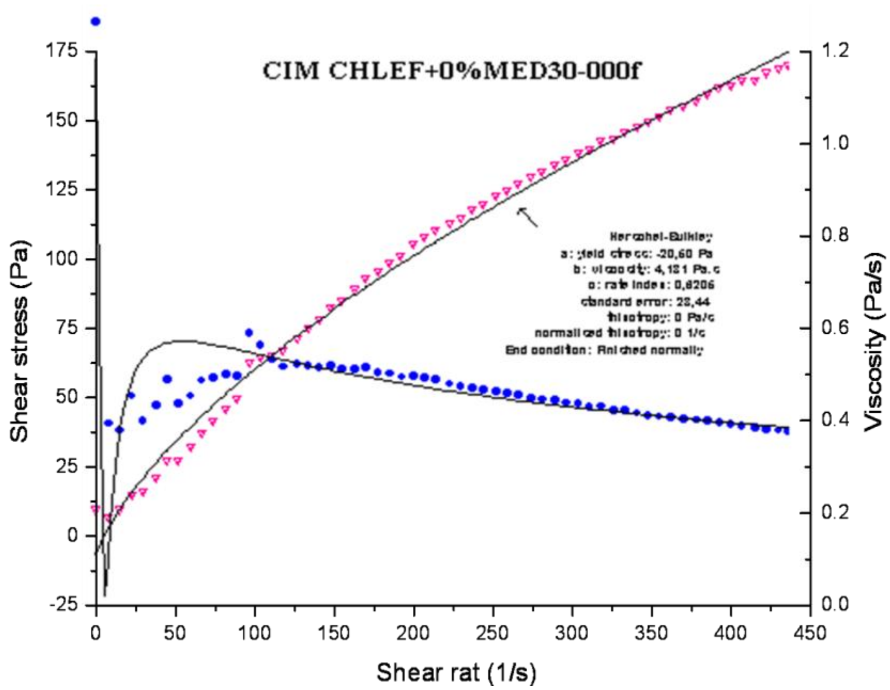

Figure 5. Paste (Cement + 0% Chlef Medaflow 30). First formulation (Cement CHLEF + Medaflow 30).

days, and 35 to 45 Mpa at 25 days (Figures 4 and 5).

Rheological cement pastes

The second part of the work is devoted to the study of rheological cement pastes. The aim of this part of the work is to determine the dosage of superplasticizer saturation which is to be several variations of pulp were analyzed rheometer AR 2000, several dosages in superplasticizers. The rheological curves are shown in Figure 6 to Figure 12 below:

For this purpose, four cement pastes were prepared. The proportions of these paste mixtures were prepared so that they are similar to the pastes in the concrete

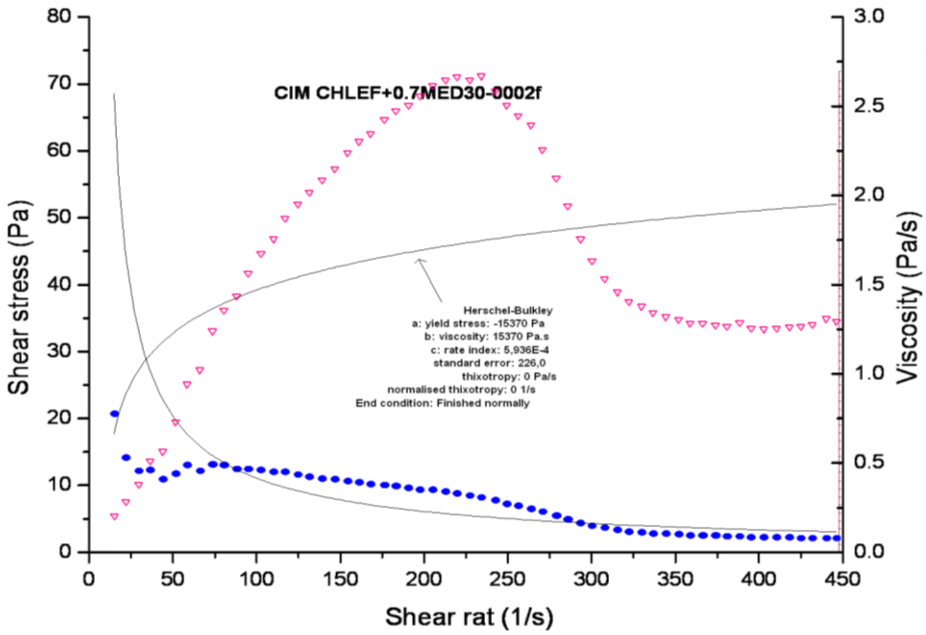

Figure 6. Paste (Cement + 0.75% Chlef Medaflow 30). First formulation (Cement CHLEF + Medaflow 30).

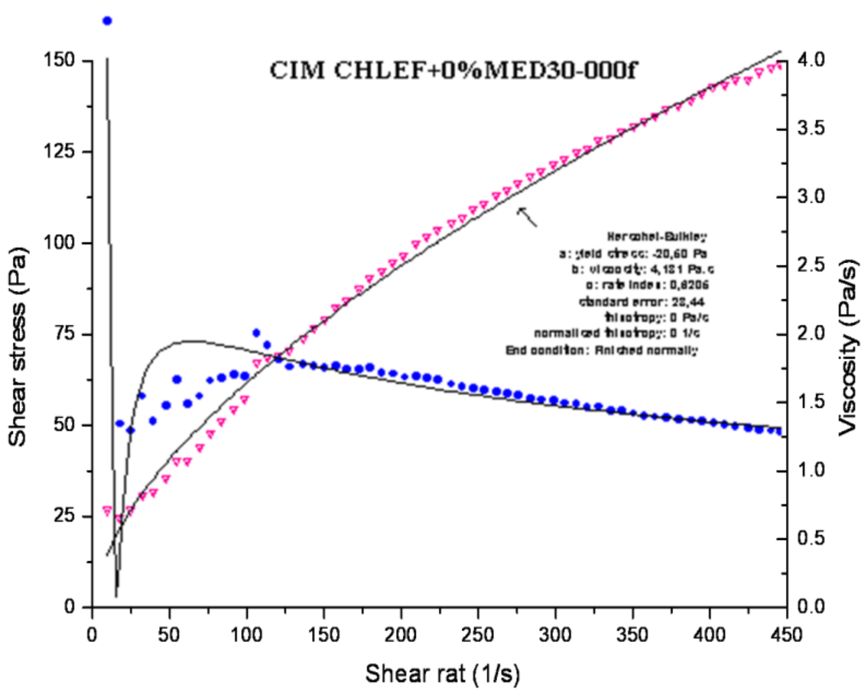

Figure 7. Paste (Cement Chlef +0.25% SP40). Second formulation (Cement Chlef + Medaplast SP 40).

mixtures, so all pastes contained the same quantity of cement, water and silica fume, but the dosage ranging of superplasticizers are varied from 0, 0.25, and 0.75 for Medaflow 30, and from 0, 0.25, and 0.50%. The other hand, the dosage of Medaplast 40 is varied from 0.25 utile 0.5 %, as shown in rheological testes in Figure 7, 8

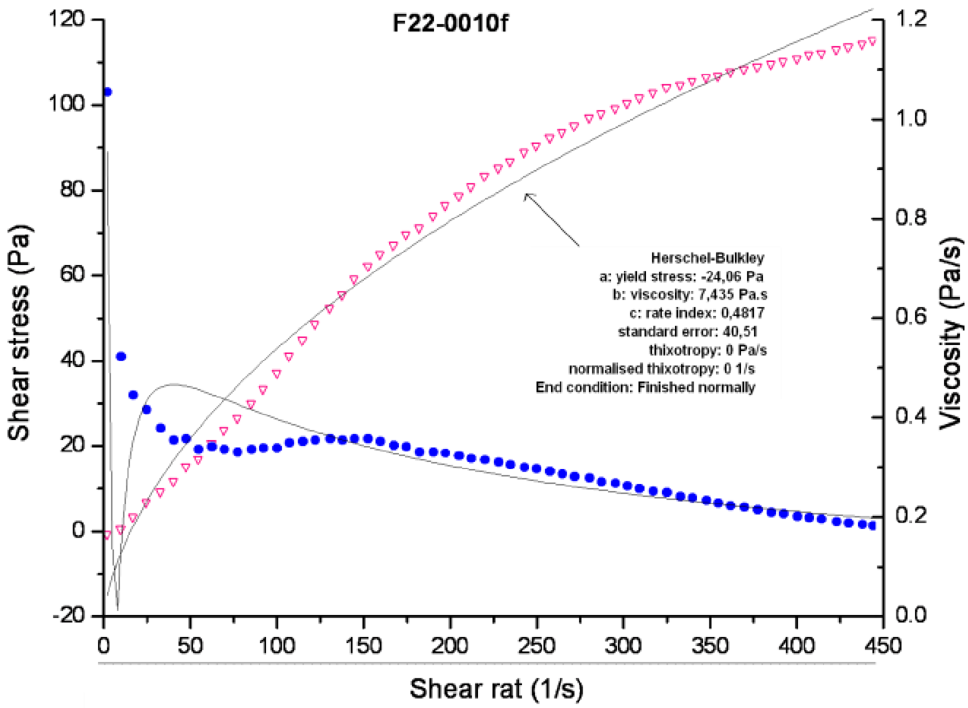

Figure 8. Paste (Cement Chlef +0.75% SP 40). Second formulation (Cement Chlef + Medaplast SP 40).

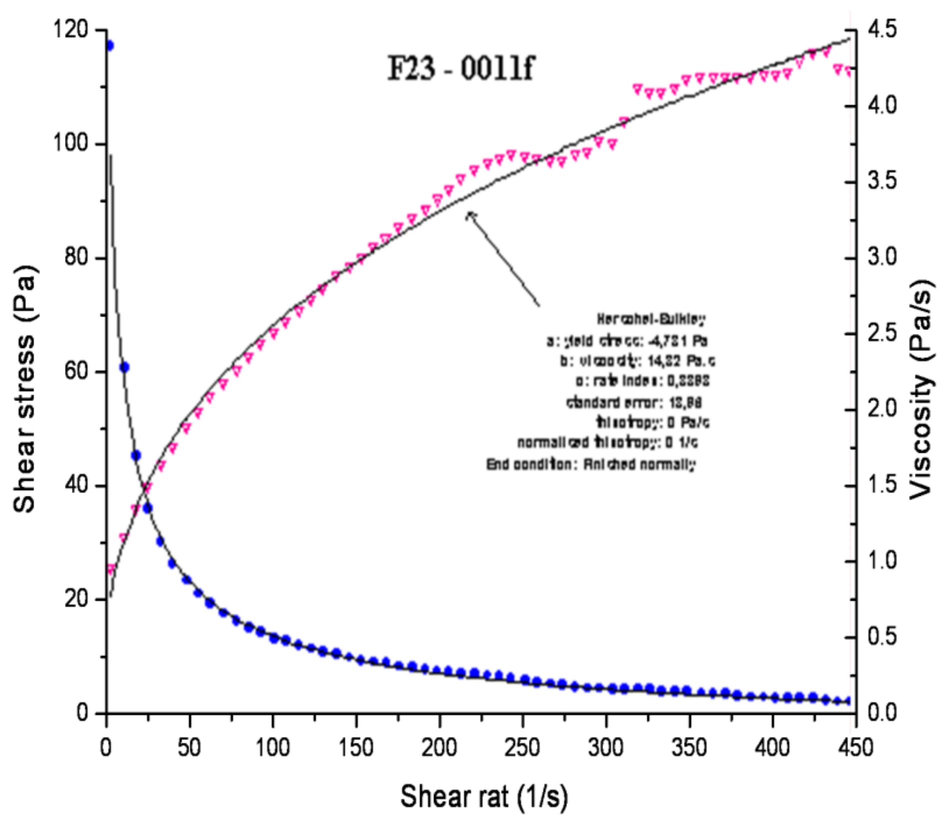

Figure 9. Paste (Cement ACC +0.25% Medaflow 30). Third formulation (Cement ACC + Medaflow 30).

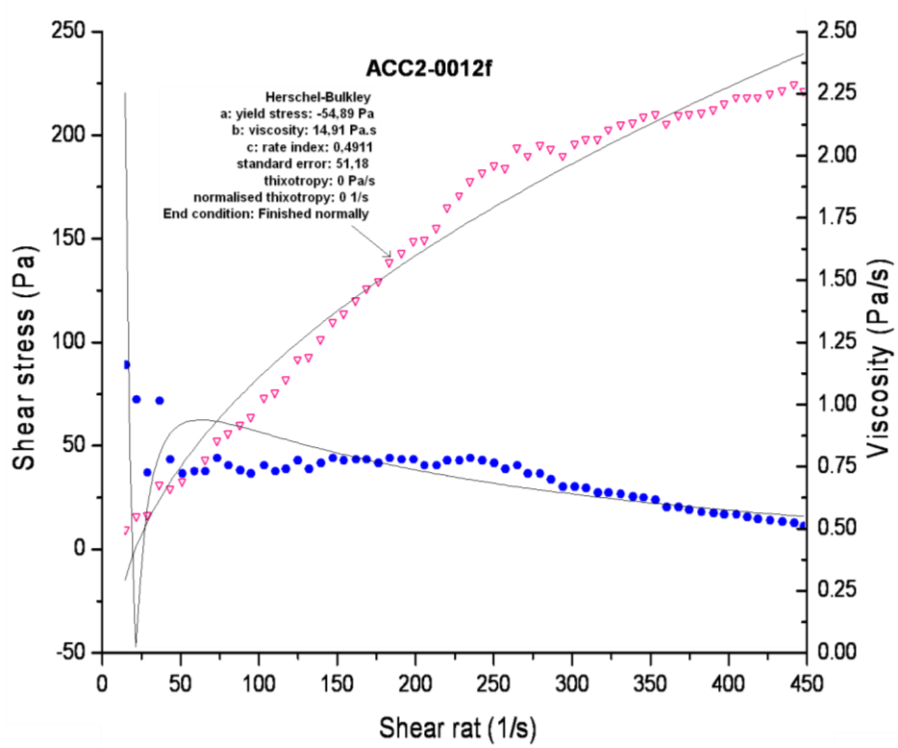

Figure 10. Paste (Cement ACC +0.5% Medaflow 30). Third formulation (Cement ACC + Medaflow 30).

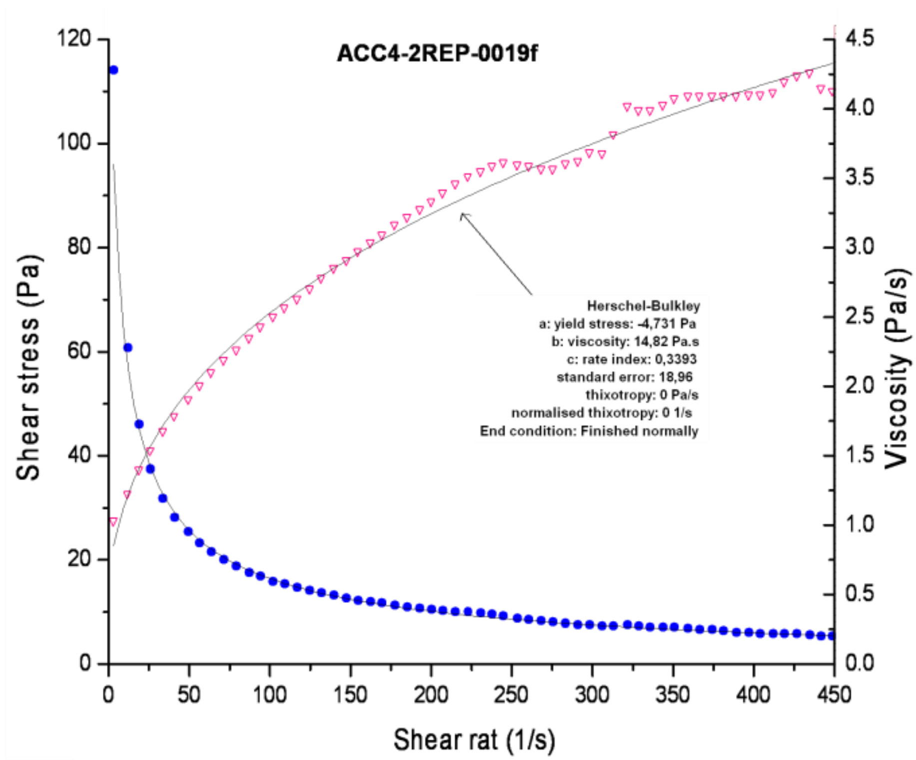

Figure 11. Paste (Cement ACC +0.5% Medaplast SP 40). Fourth formulation (ACC Cement Medaplast + SP 40).

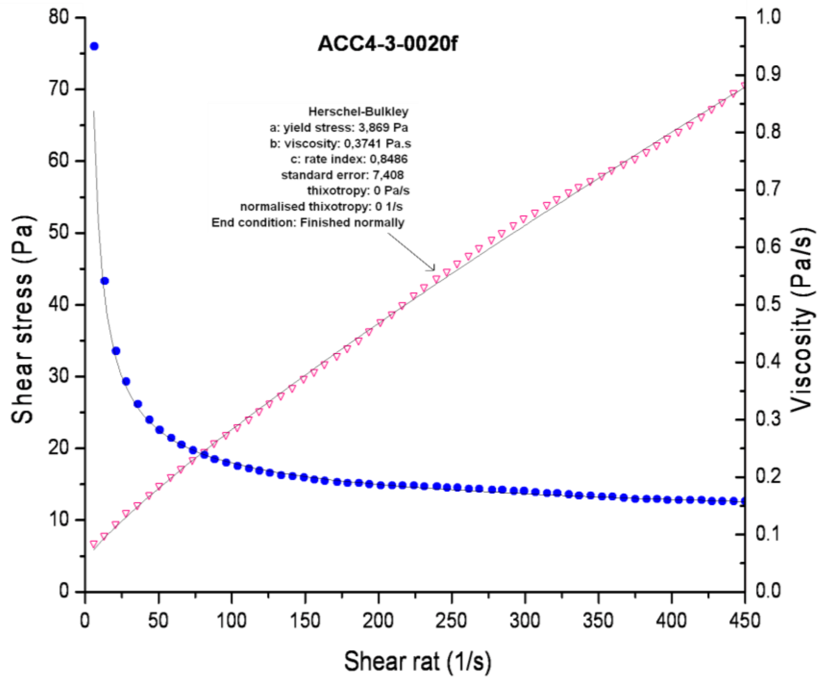

Figure 12. Paste (Cement ACC +0.5% Medaflow 30). Fourth formulation (ACC Cement Medaplast + SP 40).

and 11.

DISCUSSION

Results of rheological test show that the dosage of superplasticizer (Medaflow 30) polycarboxylate is lower than those of type sulfonated polynaphthalene in both of cement paste formulation.

According to mineralogical compositions of the two cements, the percentages of C_3A and C_4AF in cement ACC are higher than those of Chlef cement, as the superplasticizers have a preference to adsorb on the charges is higher than those present on the surfaces of silicate (C_3S and C_2S).

The percentages obtained superplasticizers are high compared to those found in the literature, this is explained by a very high surface area of the silica fume (200 m^2/g), and the architecture and shape of a large superplasticizers influence on the affinity (superplasticizer cement grain), which explains the difference of the percentages of superplasticizers found during the rheological tests and those obtained on SCC fresh.

The rheograms show that cement pastes studied elapse following the Herschel-Bulkley model, which governs the flow threshold materials (flowing with application of low critical stress).

Conclusion

In this paper, SCC elaborated from local materials (Algeria) based on Japanese formulation method. We fixed dosage of silica fume at 15% to cement content, the characterization of fresh concrete, given a good result. The diameter of the cake obtained is between 650 and 750 mm, the percentage of milt in the sieve stability is <15% and the L-box test, confirm that the SCC flows through without blocking in reinforcements with is explained by the high fluidity and absence of segregation aluminates, which the presence on surface of positive given by the incorporation of superplasticizers which suspend the cement.

The mechanical strength results are higher than 25 MPa for compressive strength, which show a very low porosity, this is due to the filler effect of silica fume and the is equal to 0.42 less than the normal concrete.

The rheograms obtained demonstrate the effect of superplasticizers on cement grout flow studied, which are materials flow threshold and follows the rheological model of Herschel-Bulkley. The viscosity of the cement pastes studied is inversely proportional to the percentage of superplasticizer incorporated, up to a saturation assay where the viscosity remains fixe, which corresponds to a minimum threshold stress, and flow problems.

REFERENCES

Bouzoubaa N, Lachemi M (2001). Self-compacting concrete incorporating high volumes of class F fly ash: Preliminary results. J. Cem. Concr. 31:413–20.

Cyr M, Legrand C, Mouret M (2000). Study of the shear thickening effect of superplasticizers on the rheological behaviour of cement

Heba A (2011). Effect of fly ash and silica fume on compressive strength of self-compacting concrete under different curing conditions. Ain Shams University, Department of Structural Engineering, Faculty of Engineering, Zagazig University, Egypt. J. Ain Shams Eng. 2:79–86.

Malhotra VM, Mehta PK (2002). High-performance, high-volume fly ash concrete. Suppl. Cem. Mater. Sustain. Dev. Inc. Canada, 24(7):30-34.

Miura N, Takeda N, Chikamatsu R, Sogo S (1993). Application of super workable concrete to reinforced concrete structures with difficult construction conditions. Special Publication, Am. Concr. Inst. USA 140:163–186.

Nocher M (2001). Flowing Smoothly and Quietly. Advanced Concrete and Masonry Center, Concrete Quarterly, UK. p. 198.

Park CK, Noh MH, Park TH (2005). Rheological properties of cementitious materials containing mineral admixtures. J. Cem. Concr. 35:842–849.

pastes containing or not mineral additives. J. Cem. Concr. 30:1477–1483.

Perssoiv B (1998). Technical Report, Japan Society for the Promotion of Science, Division of Building Materials, Lund Institute of Technology, Japan, 9803:12.

Philippe T (2004). Formulation influence on the withdrawal and cracking of self compacting concrete. Doctoral thesis, Nantes Central School, pp. 20-32.

Rafat S (2011). Utilization of silica fume in concrete: Review of hardened properties, Resources, Conservation and Recycling. pp. 923-932.

Raharjo D, Subakti A , Tavio (2013). Mixed Concrete Optimization Using Fly Ash, Silica Fume and Iron Slag. Procedia Eng. 54:827–839.

Salem TM (2002). Electrical conductivity and rheological properties of ordinary Portland cement-silica fume and calcium hydroxide-silica fume pastes. J. Cem. Concr. 32:1473–1481.

Steven HK, Beatrix K, William CP, Normand FM, Richard JM (2004). Dosage and control of concrete mixtures. Eng. Newslett. Canada 7 (101):57-72.

Yahia A, Tanimura M, Shimabukuro A, Shimoyama Y (1999). Effect of rheological parameters on self compactability of concrete containing various mineral admixtures. Proceedings of the First RILEM International Symposium on Self-compacting Concrete, Stockholm, pp. 523–535.

Zhang X, Han J (2000). The effect of ultra-fine admixture on the rheological property of cement paste. J. Cem. Concr. 30:827–830.