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Full Length Research Paper

Electrical study of plasticized carboxy methylcellulose based solid polymer electrolyte

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The electrical conductivity and thermal conductivity of carboxyl methylcellulose doped with oleic acid and plasticized with glycerol have been measured by the electrical impedance spectroscopy method in the temperature range of 303 – 393 K. The composition of glycerol was varied between 0 and 50 wt. % and the samples were prepared via solution casting technique. The highest ionic conductivity at room temperature, σ_{rt} (303K) is 1.64 x 10^{-4} S cm^{-1} for sample containing 40 wt. % of glycerol. The system was found to obey Arrhenius rule where $R^2 \approx 1$. The dielectric study (ε^*, M^*) shows a non-Debye behavior.

Key words: Solid polymer electrolyte, carboxyl methylcellulose, oleic acid, glycerol.

INTRODUCTION

Solid Polymer Electrolytes (SPEs) are the great interests for researchers nowadays, due to their wider range of tremendous applications in electrochemical devices. SPEs also offer numerous of advantages, for example, they can eliminate corrosive solvent and harmful gas formation, have wider electrochemical and thermal stability range as well as low volatility with easy handling. Recently, biodegradable materials attract enormous attention worldwide as a result of white pollution, one of the environmental crises.

According to Guo et al. (2011), plasticizers would make the polymer softer and more flexible, and enhance the chemical and mechanical stability of membranes since they could penetrate and increase the distance of molecules and decrease the polar groups of polymer. In addition, it could overcome the main shortcoming of synthetic polymer, which is mostly insoluble in the solvents. In SPEs, the polymer acts as solvent for a salt which will be partially dissociated in the matrix, leading to ionic conductivity. The electrochemical properties of such polymers are limited by the solvent and the conductivity occurs via interconnected structures of solvent and ions.

To fulfill the stipulations on biodegradable and environmental friendly materials which are significant toward the development of a green nation, carboxy methylcellulose (CMC) has been chosen in this research due to its superior properties as the polymer host. To enhance the conductivity of SPEs, the contribution of mixing polymer and ionic dopant based on the modified double lattice (MDL) is necessary (Pai et al., 2005) thus oleic acid (OA) was chosen to be used as the ionic dopant. In addition, glycerol as plasticizer is introduced

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into the polymer-dopant system in order to enhance the conductivity and the mechanical properties of the SPEs.

EXPERIMENTAL METHODS

Sample preparation

The CMC based SPEs were prepared by using the solution casting technique. 1 g of CMC (weighted by a digital mass balance) was mixed with 33 ml distilled water and stirred continuously until the CMC dissolved. 20 wt. % (0.25 g) of OA was dissolved in the CMC solution. The CMC-OA composition is following the research of Chai and Isa (2013) of the highest ionic conductivity SPE. In addition to the previous work, the CMC-OA solution was added with different composition of glycerol (0 – 50 wt. %) as plasticizer for each sample respectively. The mixture of CMC-OA-glycerol was poured into Petri dishes and dried in an oven at 60℃. The samples were then kept in desiccators for further drying process.

Electrical impedance spectroscopy (EIS)

The EIS (HIOKI 3532-50 LCR Hi-Tester) are interfaced to a computer with frequency of 50 Hz to 1 MHz. The films was cut into a fitting size and placed between the stainless steel blocking electrodes of the sample holder which connected with the LCR (Inductance, Capacitance, and Resistance) tester. The software controlling the measurement also calculates the real and imaginary impedance. The bulk impedance, R_b value was obtained from the plot of negative imaginary impedance; $-Z_i$ versus real part, Z_r of impedance and the conductivity of the sample was calculated as follow:

$$\sigma = \frac{t}{R_b A} \tag{1}$$

Where A= area of film–electrode contact and t=thickness of the film. Complex dielectric constant, and complex electrical modulus, are evaluated from the recorded complex impedance data, for each temperature. The complex permittivity and complex electrical modulus is given by:

$$\varepsilon_r(\omega) = \frac{Z_i}{\omega C_o (Z_r^2 + Z_i^2)} \tag{2}$$

$$\varepsilon_i(\omega) = \frac{Z_r}{\omega C_o (Z_r^2 + Z_i^2)} \tag{3}$$

$$M_r(\omega) = \frac{\varepsilon_r}{(\varepsilon_r^2 + \varepsilon_i^2)} \tag{4}$$

$$M_i(\omega) = \frac{\varepsilon_i}{(\varepsilon_r^2 + \varepsilon_i^2)} \tag{5}$$

Here, $C_o = \varepsilon_o A/t$ (ε_o is permittivity of free space, A is electrode–electrolyte contact area, and t is thickness of the electrolyte) and $\omega = 2\pi f$

RESULTS AND DISCUSSION

Conductivity study

The ionic conductivity is depending of various factors, such as cation and anion types, salt concentration and temperature. The ionic conductivity, σ, of CMC-OA-glycerol was depicted in Figure 1. From Figure 1, it is noted that by the addition of plasticizer affected the conductivity of the CMC-OA-glycerol SPEs. It can be observed that the ionic conductivity in this system increases until 40 wt. % of glycerol and decreases with the addition of higher than 40 wt. % of glycerol. The dependence of ionic conductivity on the plasticizers concentration provides more information on the specific interaction among ionic dopant, polymer matrix and plasticizer. The initial increase of ionic conductivity can be explained by association of ions at higher plasticizer concentration, which leads to the formation of ion clusters and the number of charge carriers and their mobility. When the amount of plasticizer is increased, the ions would transport mainly in the plasticizer-rich phase (Ibrahim et al., 2012). According to Bandara et al. (1998) by postulating the existence of separate ionic pathways for the migration of free ions through the plasticizer, it is possible to explain the enhancement of ionic conductivity when plasticizer is introduced. On the other hand, the decrement of conductivity is mainly due to the higher amount of glycerol which contributed to the overcrowd of ions thus reduces the number of charge carriers further gives limitation on the mobility of ions (Selvasekarapandian et al., 2005; Khiar et al., 2006). For further understanding on the ionic conductivity mechanism, the ionic conductivity of SPEs were tested at elevated temperature ranges from 313 to 393 K. From Figure 2, the relationship between conductivity and temperature of the SPEs are naturally Arrhenius behaviour. The regression values, R^2, obtained for the temperature dependence is R^2~1. Hence, proven the samples obey the Arrhenius law and it is thermally activated similar to the work done by Khiar et al. (2006); Nik Aziz et al. (2010) and Chai and Isa, 2012). The relation of Arrhenius law can be explained by:

$$\sigma = \sigma_o \exp(-E_a / kT) \tag{6}$$

Where σ_o is the pre-exponential factor, $E_a$is activation energy, k is Boltzmann constant and T is absolute temperature. The activation energy, E_a was calculated from the equation and shown in Figure 3.

Dielectric study

The dielectric constant is a measure of stored charge in a material (Khiar et al., 2006) where in polymer electrolytes, the charge carriers are ions. Meanwhile, dielectric loss explained the loss of energy which eventually produces a rise in temperature of a dielectric placed in an alternating electrical field. In the dielectric constant and dielectric loss plotted shown in Figure 4, no appreciable relaxation peaks observed in the frequency

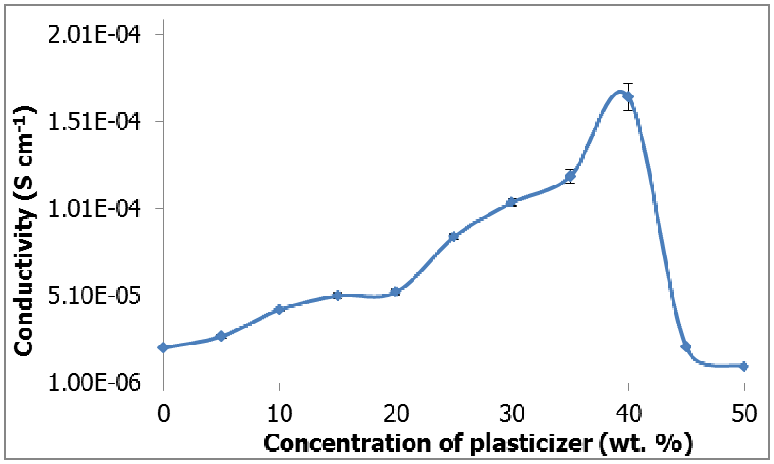


Figure 1. The conductivity of CMC-OA-glycerolSPEs at room temperature.

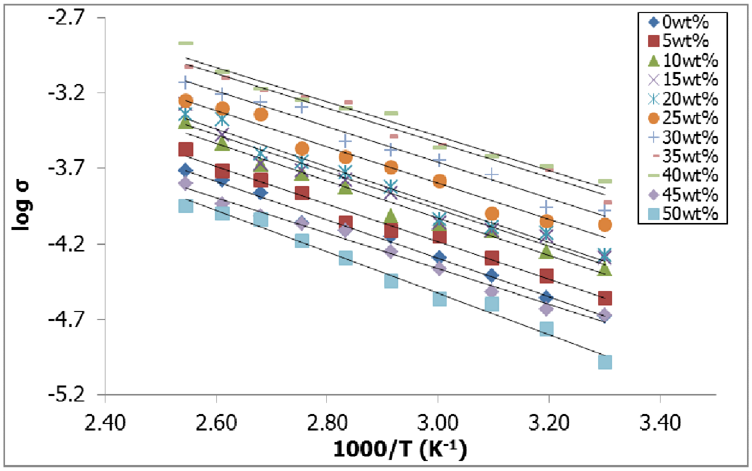


Figure 2. The Arrhenius plot of plasticized SPEs with different wt% of plasticizer.

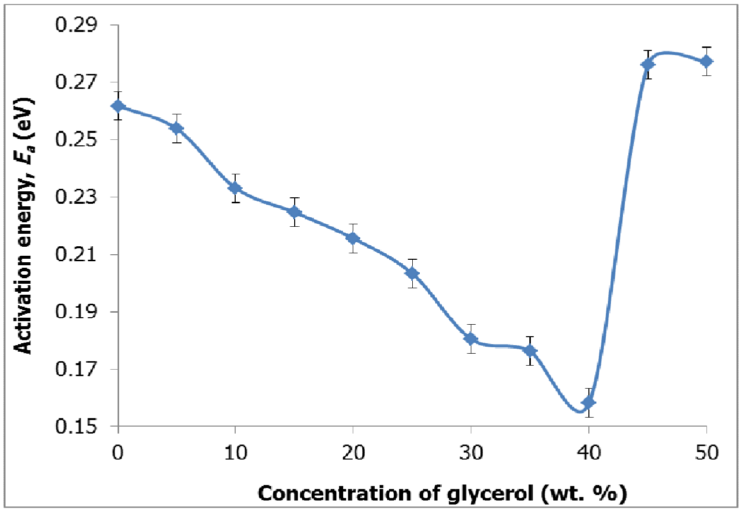
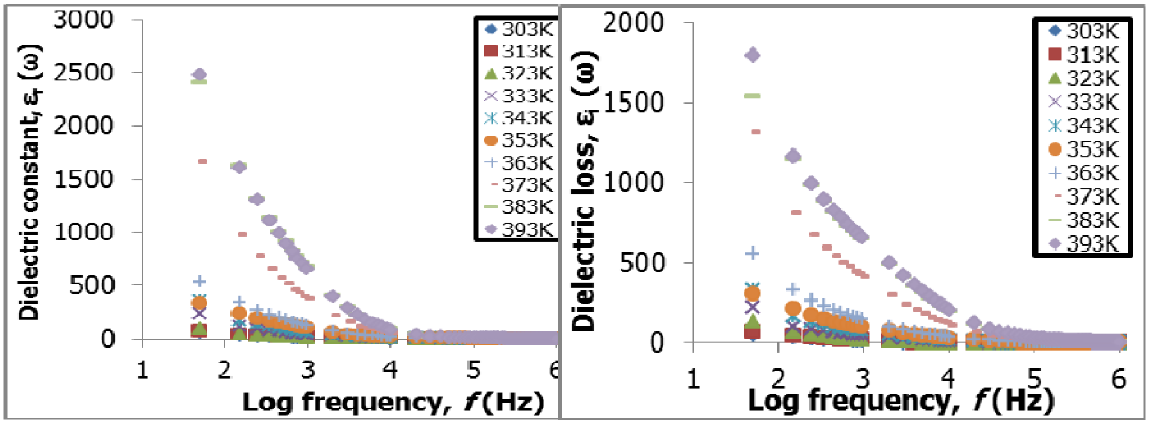
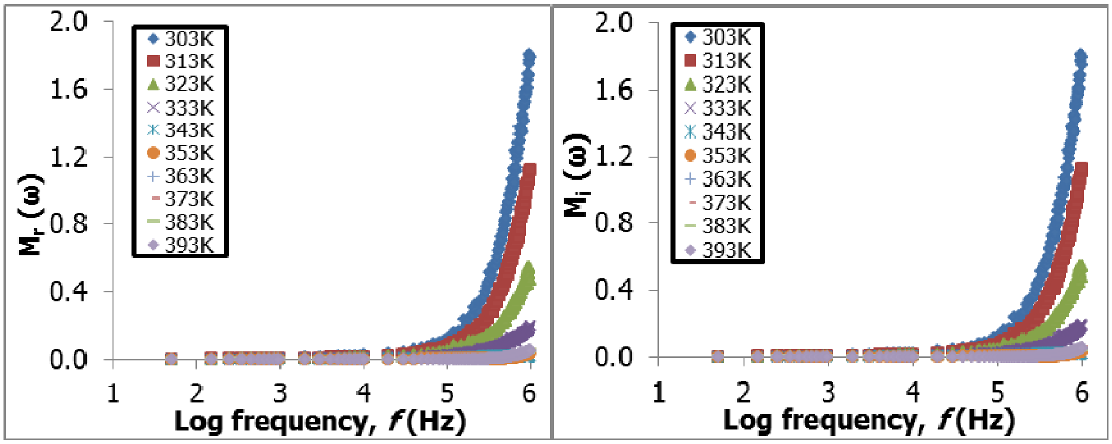


Figure 3. The activation energy of CMC-OA-glycerol SPEs.



(a) (b)

Figure 4. Frequency dependence of (a) dielectric constant, ε_r and (b) dielectric loss, ε_i at various temperatures for sample with 40 wt. % of glycerol.



(a) (b)

Figure 5. Frequency dependence of (a) real part, M_r and (b) imaginary part, M_i of modulus study at various temperatures for sample with 40 wt. % of glycerol.

range employed in this study. Both dielectric constant and loss rise sharply at low frequencies indicating that electrode polarization and space charge effects have occurred confirming non-Debye dependence. According to Khiar et al. (2006), this implied that the conductivity exhibits relaxation that is non-exponential in time. The dielectric constant in this present study indicates the increase in conductivity is mainly due to the increase in the number density of mobile ions which was also found in Majid and Arof (2007*)* and Khiar and Arof (2010). Based on their work and the similar result obtained in this current study, it can be deduced that as the frequency increases, the rate of reversal of the electric field also increases, as such; there is no charge build up at the interface which brings about a decrease in the values of the dielectric loss due to the decrease of the polarization effect by the charge accumulated. Further analysis of the dielectric behaviour would be more successfully achieved using dielectric modulus, which suppresses the effect of electrode polarization.

Modulus study

The variations of real, M_r and imaginary, M_i parts of electrical modulus are shown in Figure 5 (a) and (b) respectively. It can be observed from Figure 5, both M_i and M_r value are approaching zero at low frequency and increases at the higher frequency but no relaxation peaks can be observed. According to Khiar et al. (2006) the presence of peaks in the modulus formalism at higher frequencies for all polymer systems and temperatures is an indicator that the polymer electrolyte films are ionic conductors. The value of both M_r and M_i at low frequencies indicates that electrode polarization is negligible. The appearance of a long tail at low frequencies indicates that there might be a large capacitance associated with the electrodes which further confirms non-Debye behavior in the samples (Nik Aziz et al., 2010).

Conclusion

Solid polymer electrolytes based on CMC-OA plasticized with glycerol were prepared. Sample with 40 wt. % of glycerol was found to have the highest ionic conductivity at room temperature (303 K) of 1.64 x 10^{-4} S cm^{-1}. The ionic conductivity results as a function of temperature exhibited Arrhenius rule and the value of activation energy is capsized of conductivity. Dielectric study and modulus study suggests that samples in this study show non-Debye behaviour.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGMENT

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Full Length Research Paper

Strength improvement of a High Performance Fiber Reinforced Concrete (HPFRC) containing local raw materials

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Improvement of mechanical strength of a High Performance Fiber Reinforced Concrete (HPFRC) containing local raw materials at a cheap rate was investigated in this present work. An experimental study was conducted on different concretes based on dune sand and reinforced by metallic fibers. The concretes studied are formulated based on a Portland Cement (PC), Dune Sand (DS), Dust of Electro-filter (DE), Metallic Fibers (MF) and Superplasticizer (SP). The obtained results show that it is possible to manufacture concrete based local raw materials (inexpensive) giving compressive strength of about 105 MPa, with an improvement in ductility resulting from a tensile strength up to 20 MPa. Also, this strength improvement of the studied concrete is ensured by a simple heat treatment at a temperature of 90°C for 48 h after 28 days of curing.

Key words: Sand of dunes, dust of electro-filter, high performance fibers concrete (HPFC) thermal treatment, mechanical properties.

INTRODUCTION

Progress in the manufacture field of cement, of additive and the incorporation of other components (fibers and fines) in the concrete compositions with the reduction of Dmax of aggregates to ensure the maximum material compactness gave rise to a new generation of the concretes (UHPFC, ultra high performance fiber concrete) (Rougeau and Borys, 2004; Rossi et al., 1996; Maeder et al., 2004). These concretes are more resistant and compact and confer best durability compared to other concrete types (Long et al., 2002).

Generally, an additive fines used in the HPFC composition are the crushed siliceous sand and the silica fume; the scarcity of the latter and their unavailability in all the areas in Algeria leads to a more expensive material. So it is necessary to look for other types of mineral addition or to recycle the by-product as dust of electro-filter recovered during the clinker manufacture (AFPC-AFREM, 1997; Saidi et al., 2010) and dune sand finely crushed (Tafraoui, 2009; De Larrard, 1989). The choice of these matters was carried out according to two criteria:

i) The valorization of the waste which has a negative influence on the environment.
ii) The availability of the dunes sand in the southern area of Algeria.

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Table 1. Characteristics of cementitious materials.

Components (%)	Cement (C)	Dust of Electro-filter (DE)	Silica Sand (SS)	Fine Sand (FS)
SiO_2	19.31	17.02	92.03	79.07
Al_2O_3	04.91	04.14	02.77	08.06
Fe_2O_3	03.20	02.70	00.45	03.45
CaO	61.77	62.01	01.04	02.22
MgO	02.02	02.28	00.10	00.67
SO_3	02.12	01.82	00.51	00.01
$K_2O + Na_2O$	00.78	00.70	01.74	02.90
C_3S	63.08	-	-	-
C_2S	12.75	-	-	-
C_3A	05.74	-	-	-
C_4AF	01.64	-	-	-
Specific gravity (g/cm^3)	3.10	2.83	2.62	2.91
Specific surface (cm^2/g)	3900	8180	4000	-
Compressive strength (MPa)				
2 days	21.50	-	-	-
28 days	49.00	-	-	-

The addition of metal fibers ensures the ductile behavior of the HPC, in this study; the metal fibers of the cut out cables of breakdown service (pieces of diameter 0.537 mm and length 14 mm) are used (Swamy and Mangat, 1974). The essential characteristics of this type of cable are its tensile strength (Rossi, 1998).

The heat treatment is a significant factor to improve the HPFC characteristics, thus determination of the best method of treatment in water or the saturated air, the good temperature and best time belong to this study (Yazici, 2007; Sharon and Ling, 2006).

The final context of this study is to determine the effect of electro-filter dust of clinker, fibers and the heat treatment on the UHPFC characteristics. In order to improve the mechanical properties of the concretes, this work focused on the UHPFC development, to use the local raw materials and at a cheap rate (Ordinary Portland cement, natural sand, siliceous sand, cable of breakdown service vehicles and a superplasticizer).

MATERIALS AND EXPERIMENTAL PROGRAM

Cement (PC): The cement used is CEMII 42.5 type; it comes from the Algerian cement (east of Algiers). Physical, chemical, and mineralogical characteristics are given in Table 1, and are according standard norm NF EN 197-1 (AFNOR, NF IN 197-1, 2001; AFNOR, NF IN 934-2/A2, 2006).

Dust of electro-filter (DE): This dust is recovered by the electro-filter of the cement factory. It has a smoothness of 8180 cm^2 /g and contains 62% of CaO.

Dune sand (DS): In this work dune sand is used as fine sand and was sieved on a sieve 2 mm diameter, then washed on a sieve of 0.063 mm µm.

Silica sand (SS): This sand is ground and also characterized by a high percentage of silica> 90% and SSB = 4000 cm^2/g.

Fibers (MF): Metallic fibers are used as reinforcement for concrete (Table 2). These fibers are breakdown cables of service vehicles. The characterization was effected at the laboratory of the research unit (UR-MPE). For the preparation of fibers, we used the cable derange manually cut out using a grip with lengths of 14 Misters (Figure 1).

Superplasticizer (SP): A high reducing water is used as a superplasticizer of type Tempo 12 manufactured by SIKA.

Mixtures of concretes

All concrete mixtures were established using the BOUNEAU method used for HPF concrete and the AFGC recommendations (Bonneau, 1997; Bache, 1981; AFGC, 2002). Three concrete compositions in this work were chosen which are given in Table 3 and high performance concrete HPC in 1 m^3 is given in Table 4.

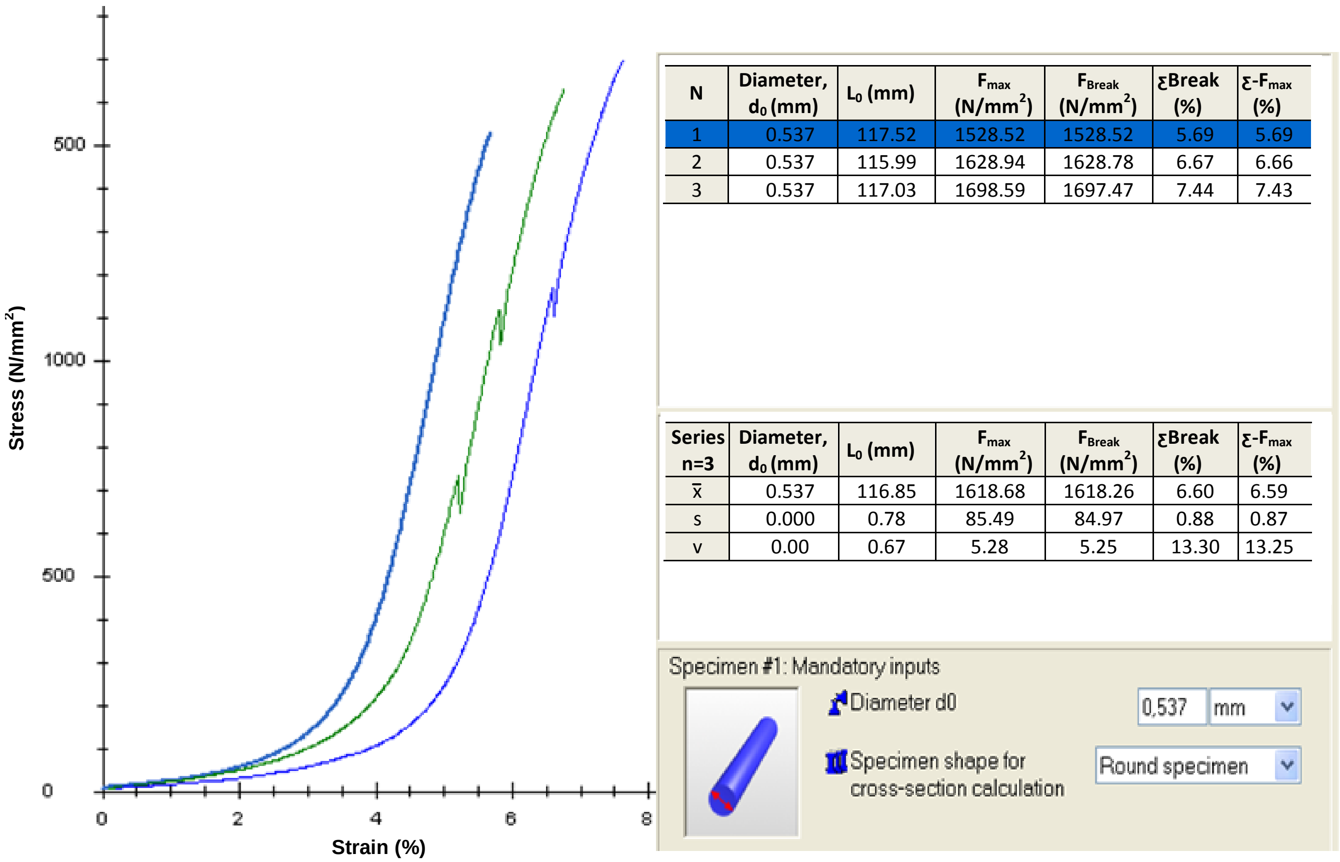
Experimental program

In order to improve the mechanical properties of the concretes, the local raw materials used in this work are the Portland Cement (PC), the Dust Electro-filter (DE), the Dune Sand (DS), Silica Sand (SS) and the Metallic Fibers (cable of breakdown service vehicles). To carry out this work after having made the characterization of the various components, the work methodology followed:

i) Optimization of the high performance concretes (HPC) with optimal dust electro-filter level by measuring the mechanical strength at 3 and 7 days;
ii) Application of heat treatment for curing (the test-tubes by immersion in water) of High Performance Fiber-reinforced Concrete (HPFC) at temperature 30, 60 and 90°C, during 4 and 24 h;
iii) Thereafter, the processing time and optimum temperature have been determined for the HPFC with better mechanical properties.

Table 2. Characteristics of metallic fibers used.

Properties	Metallic fiber
Length [mm]	14
Diameter [mm]	0.54
Bulk density [g/cm^3]	7.80
Young modulus [GPa]	-
Tensile strength [MPa]	1678
Form	Corrugated



N	Diameter, d_0 (mm)	L_0 (mm)	F_{max} (N/mm^2)	F_{Break} (N/mm^2)	εBreak (%)	ε-F_{max} (%)
1	0.537	117.52	1528.52	1528.52	5.69	5.69
2	0.537	115.99	1628.94	1628.78	6.67	6.66
3	0.537	117.03	1698.59	1697.47	7.44	7.43

Series n=3	Diameter, d_0 (mm)	L_0 (mm)	F_{max} (N/mm^2)	F_{Break} (N/mm^2)	εBreak (%)	ε-F_{max} (%)
$\bar{x}$	0.537	116.85	1618.68	1618.26	6.60	6.59
s	0.000	0.78	85.49	84.97	0.88	0.87
v	0.00	0.67	5.28	5.25	13.30	13.25

Specimen #1: Mandatory inputs

Diameter d0: 0,537 mm

Specimen shape for cross-section calculation: Round specimen

Figure 1. Mechanical behavior of fibers used (tensile test).

Casting and curing of concrete specimens

All the mixtures were mixed and prepared using a mortar mixer. Before casting, slump-flow test is attempted as workability tests on fresh concrete. Thereafter, a total of three (3) specimens were cast in prismatic molds of (40×40×160 mm^3), for each concrete mixture. One day after casting, specimens' samples were stored in water under 21±1°C.

Test methods

Rheological tests: All rheological tests were carried using a viscosimeter VT550 type with coaxial cylinder geometry (Figure 2). Rheological measurements were conducted according to following protocol (in first step: a pre-shear and a ramping of the shear rate at 350 s^{-1} during 60 s. Second step: maintaining a constant shear rate at 350 s^{-1} for 300 s). It was noted that this protocol can be used for the cementitious pastes (Safi et al., 2011; Struble and Sun, 1995; Ferraris, 1999). All cementitious pastes tested, were prepared with fixed dosage of superplasticizer and a ratio W/C = 0.29 which, was kept constant.

Tests on fresh concrete: The flow test was carried out on the studied concretes, by the Abrams cone used for HPFRC. The flow test procedure was according to specification and guidelines for self compacting concrete (EFNARC, 2002).

Tests on hardened concrete: Both the compressive and flexural strength of concrete were determined. A compressive test machine

Table 3. Concrete compositions.

Components	HPC(1)	HPC(2)	HPC(3)
PC [Kg/ m^3]	710	710	710
DS [Kg/m^3]	1020	1020	1020
SS [Kg/m^3]	220	330	110
DE [Kg/m^3]	220	110	330
SP [Kg/m^3]	15	15	15
W/C	0.29	0.29	0.29

Table 4. Formulation of high performance fiber concrete HPFC in 1 m^3.

Components	HPFC
Cement PC [Kg]	710
Sand fine DS [Kg]	1020
Sand Crushed SS [Kg]	110
Dust of electrostatic DE [Kg]	330
Superplasticizer SP [Kg]	15
Metallic fibers MF [Kg]	125
W/C	0.29

Figure 2. Equipment used for rheological tests.

was used to test concrete samples, which have been cured in saturated water at 22±1°C for 3, 7 and 28 days according to ASTM C348 and C349 (ASTM C348 – 08, 2008; ASTM C349 – 08, 2008). The bulk density is also measured for all studied concretes, according the ASTM test C642 (ASTM C642, 1993).

RESULTS AND DISCUSSION

Rheological study of cementitious pastes

The saturation point is the dosage beyond which the superplasticizer has no effect on the rheological properties of the cementitious pastes or concretes. In this work, it is determined using the viscometer VT500. The saturation point of superplasticizer with a ratio W/C = 0.29, was first determined for the cement paste of studied concretes. The results are shown in the rheograms as follows in Figures 3 and 4. Based on the viscometer records, all the shear stress curves (Figure 3) were modelled to the Herschel-Bulkley Equation (1):

$$\tau = \tau_0 + K.\dot{\gamma}^n \quad (1)$$

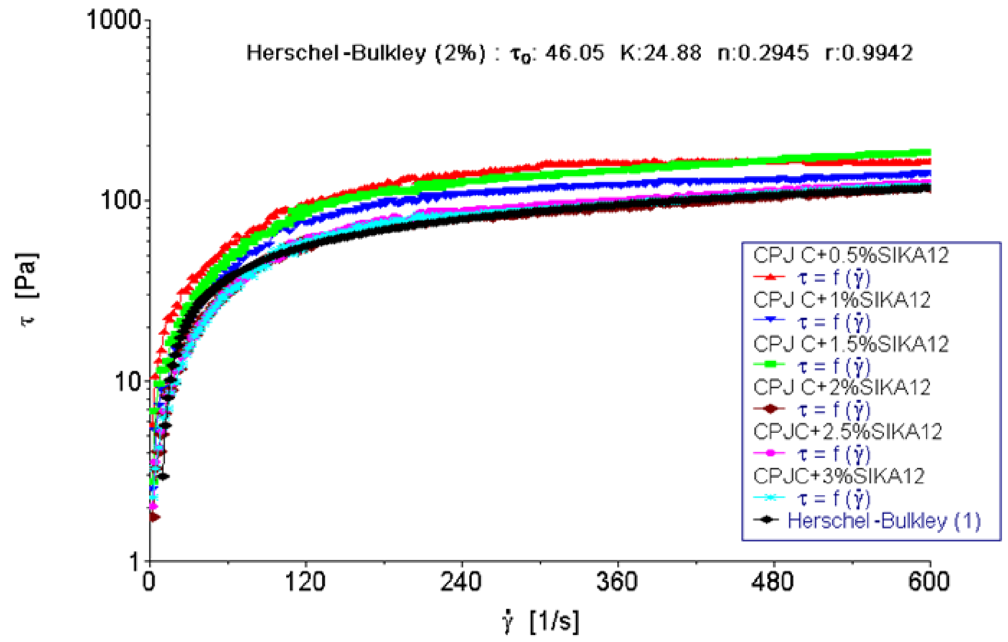


Figure 3. Variation of the shear stress as a function of shear rate.

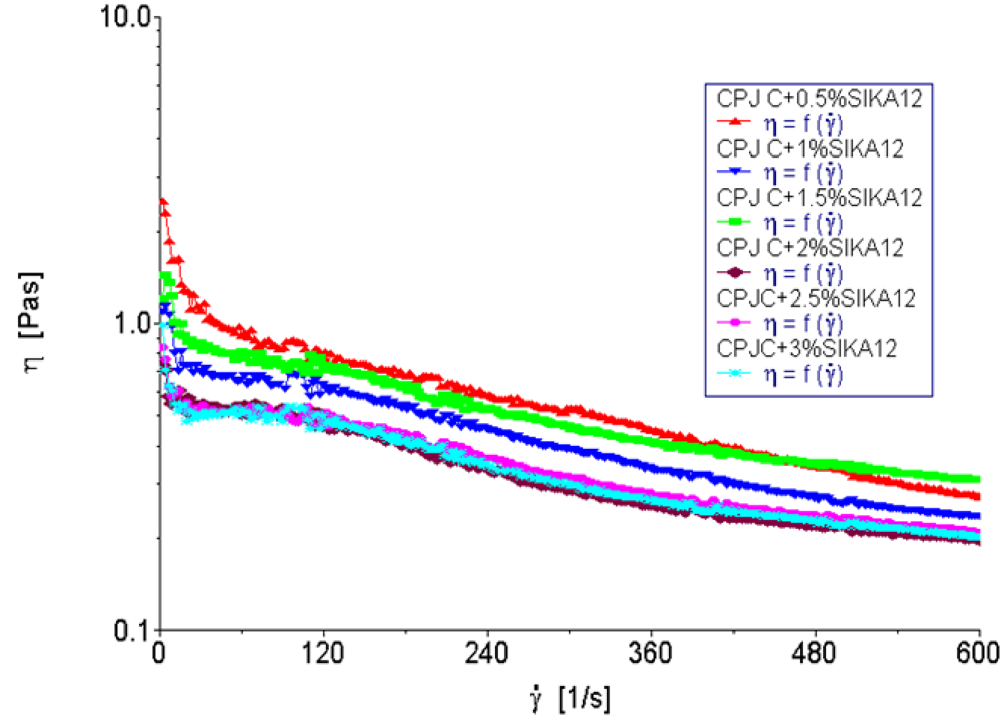


Figure 4. Variation of the plastic viscosity as a function of shear rate.

Where: τ is shear stress; τ_0 is yield stress; *K*: is consistency and γ^* is shear rate. Exponent n characterises paste behaviour: n<1 denotes shear thinning and n>1 shear thickening. Further to that rule, all the cement pastes studied exhibited shear thinning behaviour, which is in conformity to the one found in the literature (Struble and Sun, 1995; Ferraris, 1999).

After having tested cement with various proportions of

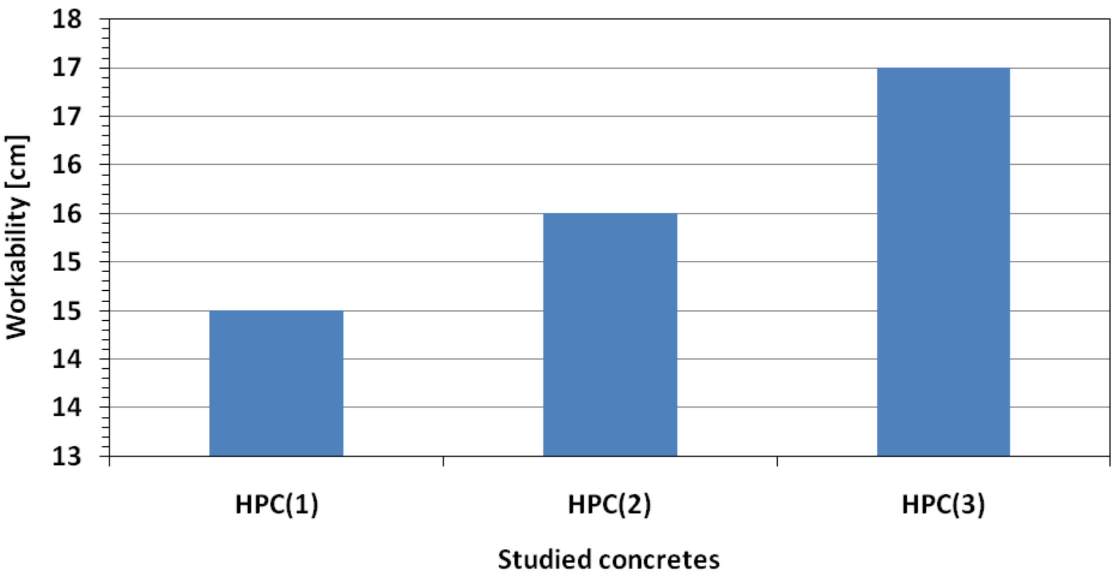


Figure 5. Slump of studied concretes.

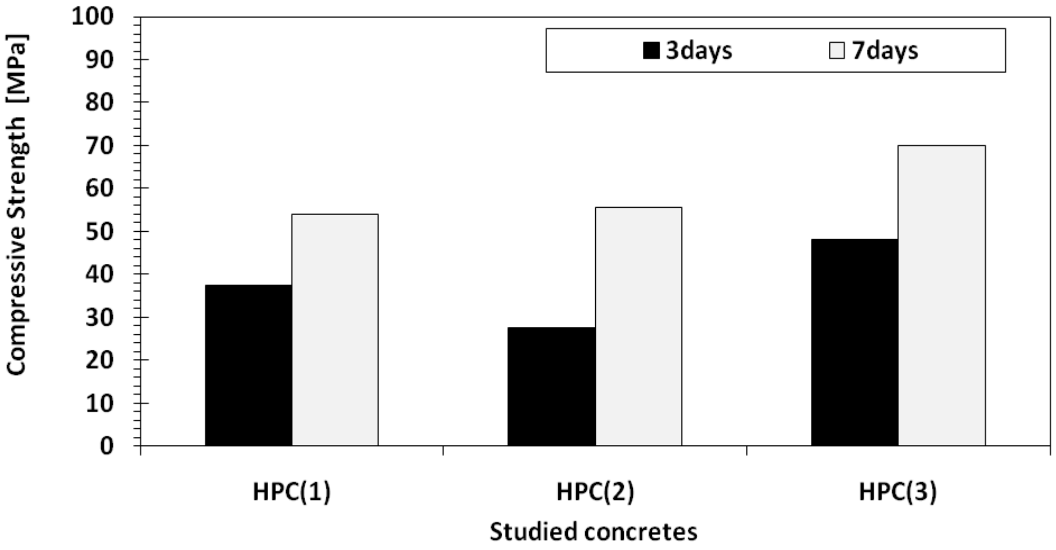


Figure 6. Compressive strength of studied concretes.

superplastifiant, it was noted that SP effect is appreciably on the main rheological parameters (plastic viscosity and shear stress) of cement pastes. Indeed, increase in the percentage of superplastifiant resulted in decrease in the viscosity and shear stress (Figure 4). That can be explained by the dispersing effect of SP which causes a steric repulsion between the cement particles, reducing their agglomeration thanks to the principal length of the superplasticizer chains as well as the grafting of the unadsorbed side chains. In addition, the more SP percentage increases, the more the flow of the cementitious pastes approaches the Newtonian flow, up to the saturation point. Besides, superplasticizer does not influence on the cement pastes flow.

Optimization of the high performance concrete

The first step will be to optimize composition of the concretes by measuring the fluidity and mechanical strength. Also, these concretes were subjected to heat treatment for different temperature chosen. The obtained results are presented in Figures 5 and 6.

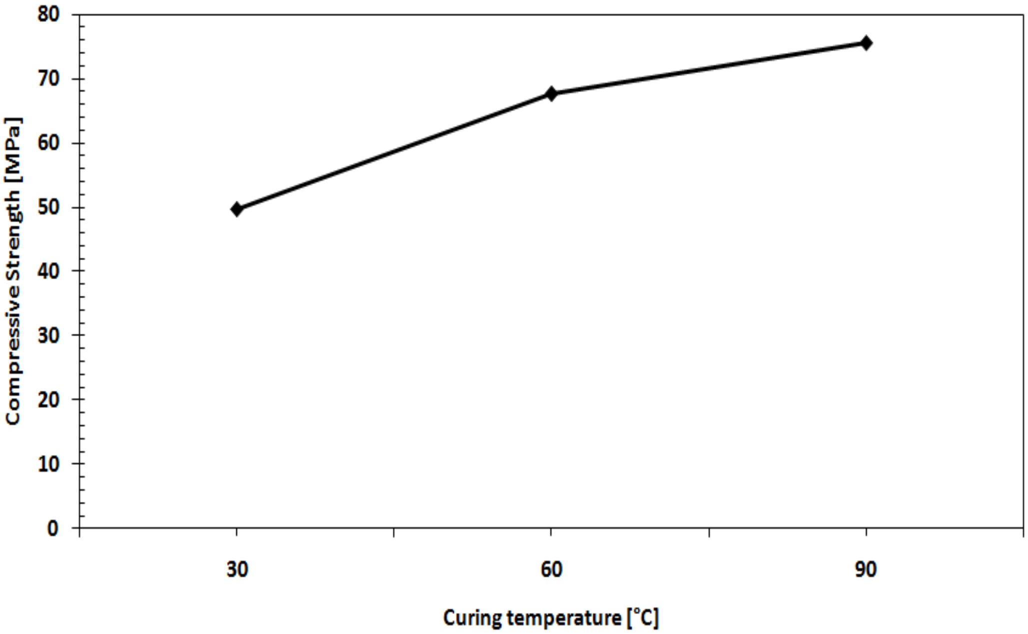


Figure 7. Compressive strength evolution as function the heat treatment.

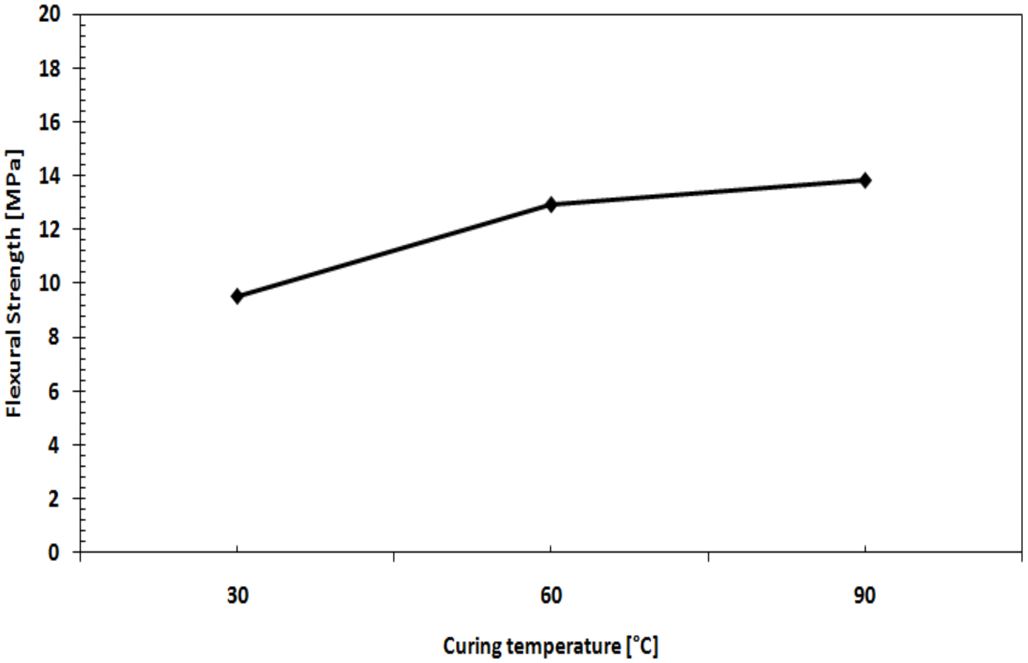


Figure 8. Flexural strength evolution as function the heat treatment.

Heat treatment by immersion of the test-tubes in water

Mechanical strength with heat treatment

The heat treatment was done by immersion of the test-tubes in a vat filled with water inside the drying oven. Figures 7 and 8 show showed the compressive and flexural strength evolution as function of the heat treatment of studied concrete. According to this result, it is clear that for strength improvement, the best suitable heat treatment is at 90°C during 24 h. Indeed, the figures

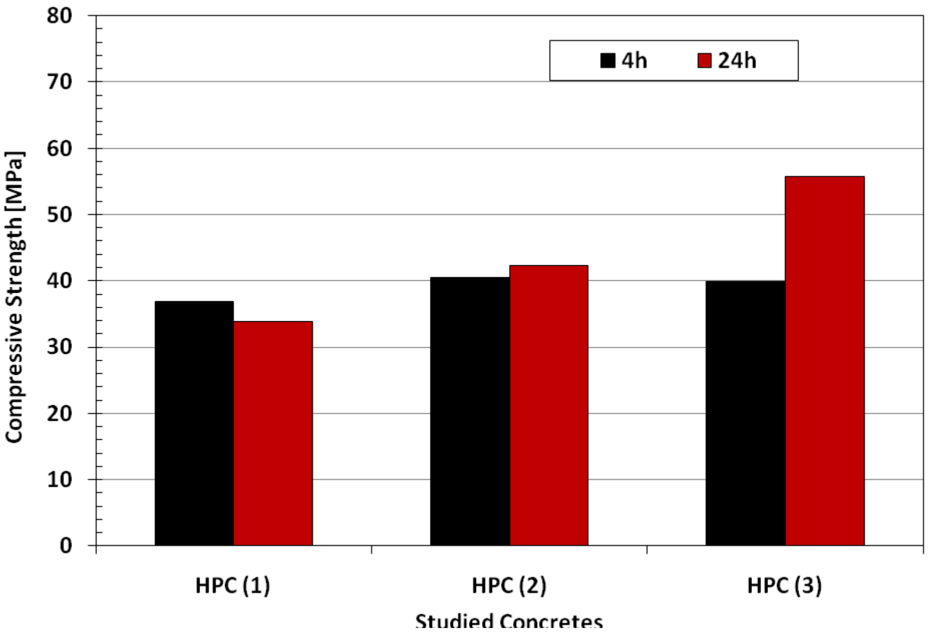


Figure 9. Compressive strength evolution as function the processing time of heat treatment.

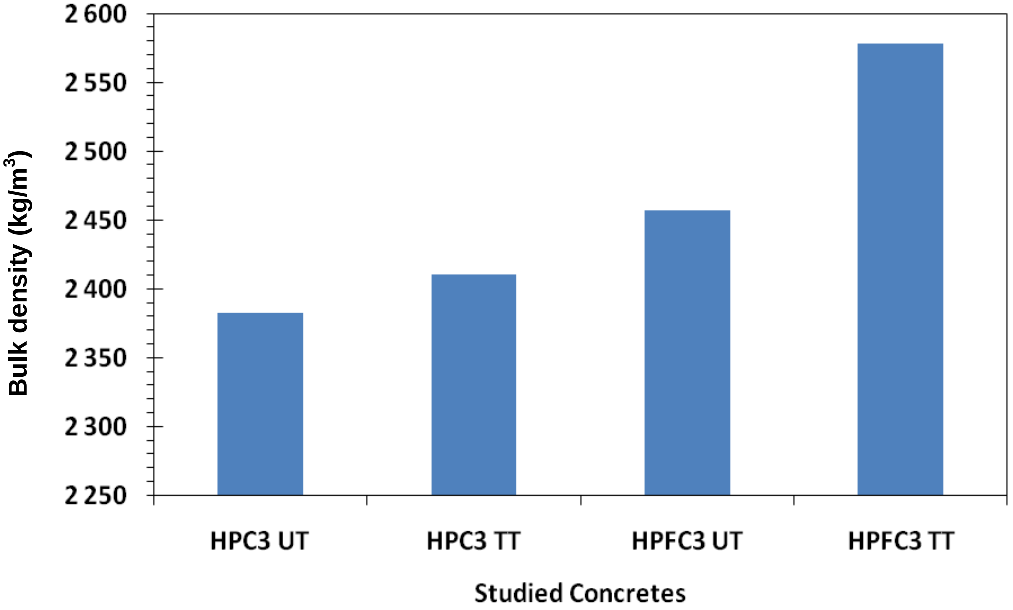


Figure 10. Bulk density of studied concretes.

show a significant increase of the compressive strength of concrete samples. Indeed, the figures show a significant increase in the compressive strength of concrete samples. This increase is about 60% for compressive strength and about 40% for flexural strength.

Figures 9 show the compressive strength evolution as a function of the processing time and of heat treatment evolution as a function of the heat treatment of studied concrete at 7 days of curing age. The obtained result show that, during 24 h of heat treatment the strength of concretes can be improved and also when compared with 4 h of treatment, the increase in strength is about 38%. The increase in strength accompanying increase in the bulk density of studied concrete can be explained by the densification of the cementitious matrix (Figure 10).

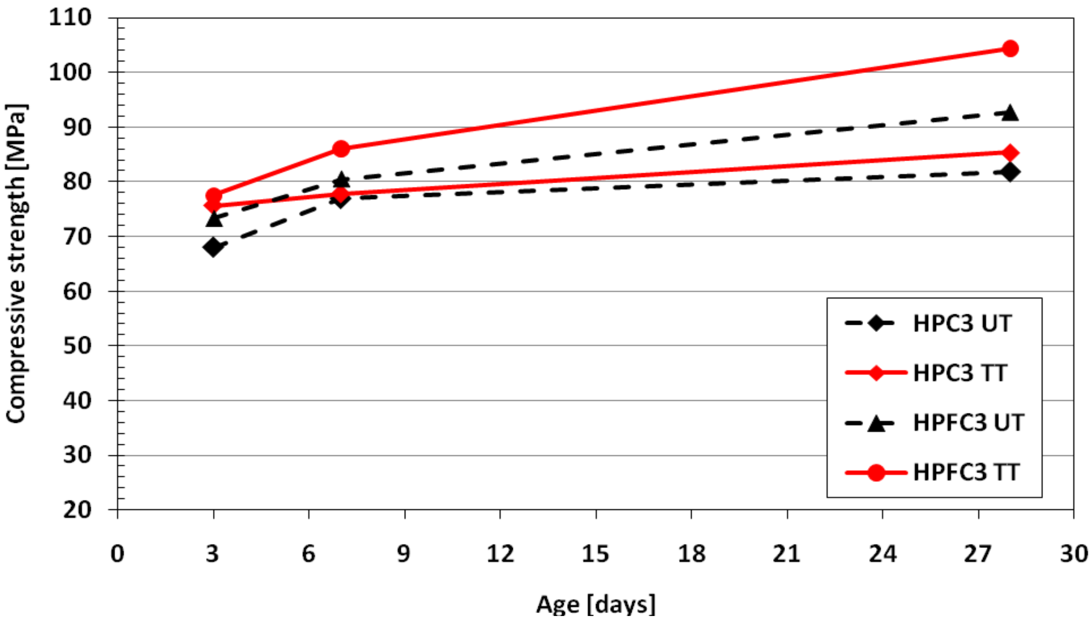


Figure 11. Compressive strength development of the studied concretes (treated and untreated) as function curing age.

According to the results obtained, it can be noted that the mechanical resistances to compression are high for the 3rd composition. Also for depression with the slump test, the HPC3 PC3 give good fluidity compared to the others. These results force to us to choose the 3rd composition and to proceed with treatment by immersion. The temperature of cure has a major role on the development of the mechanical properties of the concrete. At the youth level, all seems to show that it is simply the increase in the degree of reaction which is responsible for higher resistances at high temperature.

A rise in temperature during the first stages of hydration results in a faster hydration. According to Kjellsen et al. (1990), the influence of temperature results in a kinetic effect of the increase in temperature. This results in an acceleration from the process of hydration and the evolution of resistances, whereas reduction in the temperature slows down the process of hydration; the density and size of the crowns of inner H-S-C are increased, the portlandite crystallizes in the form of fine hexagonal plates and the sulphate rates measured in the H-S-C are more significant, and an increased polymerization of the silicate chains which is densifient and rigidifies the H-S-C, therefore obtaining a very compact structure (Kjellsen et al., 1990, 1991). Our result is similar and in agreement with works of Mouret et al. (1999).

The preceding results confirm that there is improvement in the performances of concrete samples. The next step will be preparation of high performances fiber-reinforced concrete (HPFC), with the HPC3 composition and a thermal 90°C treatment during 48 h.

Mechanical strength development of HPFC

Figures 11 and 12, given compressive and flexural strength development of the studied concretes (treated and untreated) as function curing age (3, 7 and 28 days). A significant improvement in mechanical strength (compressive and flexural) of concretes was noted and clearly observed in these figures. This improvement in strength is probably due to heat treatment suitable for concretes which have made increase of about 25% for the fiber reinforced concrete and 10% for concrete without fiber. However, heat treatment effect is more significant of the flexural strength of fiber reinforced concretes, while the improvement of strength flexural is about 37%.

Conclusion

According to experimental results, released remarks can be quoted below:

i) An increase in the compressive and flexural strength of the concretes thermally treated compared with untreated (with or without fibers). Increase in the compressive and flexural strength of the concretes thermally treated compared with untreated (fibers or not fibers).
ii) The heat treatment and fibers presence, have improved the mechanical performances of UPFC by improving the microstructure of the cementitious matrix.
iii) The purpose of the fiber addition is to improve ductility while acting on the cracking on two scales: On the scale

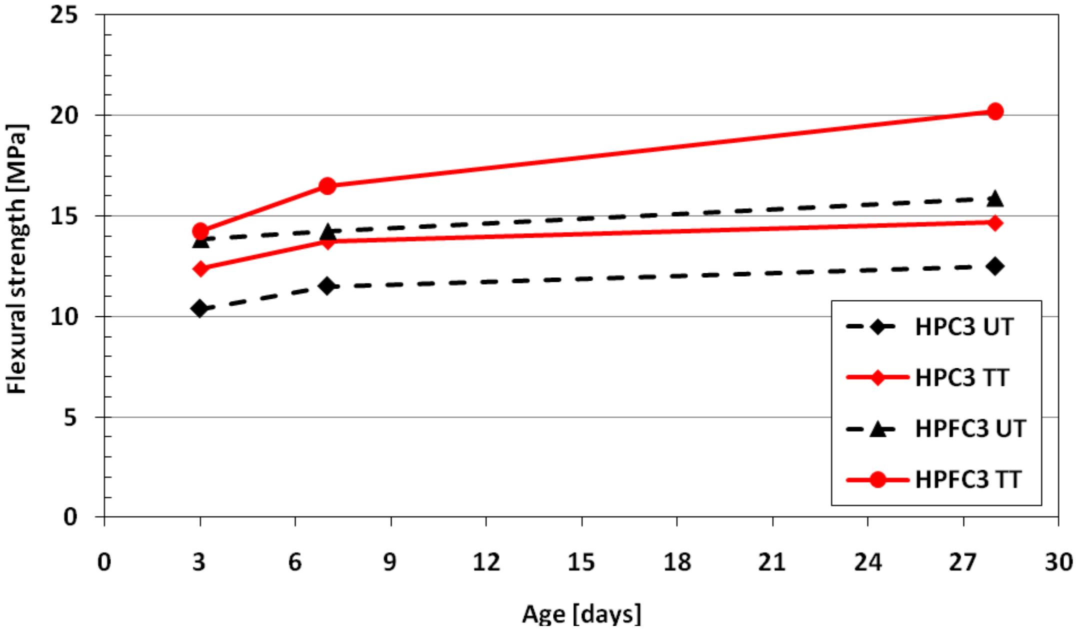


Figure 12. Flexural strength development of the studied concretes (treated and untreated) as function curing age.

of the material (increase in the tensile strength) and on the scale of the structure.

iv) The results of this work show that it is possible to make a concrete with mechanical performances acceptable, using local materials (inexpensive) such as the dust electro-filter, the dune sand and the metallic fibers of breakdown cable of service vehicles.

v) Comparatively to concretes based silica fume, concretes studied in this study may be acceptable from the viewpoint of cost price of the concrete material. Because the dust is an element which has a mineralogical and chemical composition close to that cement, therefore it can be used in substitution of silica fume.

As known, the UPFC are concretes which have a good ductility by introducing the fibers. Indeed these fibers can make obstacle the formation and propagation of the cracks which cause the damage of the structure. The fibers used in this work, have significantly improved the flexural strength reaching 15.90 MPa.

During a high thermal temperature treatment, the HPFC containing a certain percentage of fibers reach maximum compressive stresses because the fibers act on the microfissuring induced by the high thermal gradients and the mineralogical changes (104.34 MPa for compression and 20.22 MPa for the inflection).

Conflict of Interest

The authors have not declared any conflict of interest.

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Commentary

Comment on "Combined heat and mass transfer by mixed convection magnetohydrodynamic (MHD) flow along a porous plate with chemical reaction in presence of heat source" by Zueco, J. and Ahmed, S., 2010, [Appl. Math. Mech. -Engl. Ed. 31(10), pp. 1217-1230]

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In this paper, we demonstrate that the previously reported effect of the transverse magnetic field on a steady mixed convective heat and mass transfer flow of an incompressible viscous fluid past an infinite vertical isothermal porous plate considering the induced magnetic field with viscous and magnetic dissipations of energy by Zueco and Ahmed (2010) [Appl. Math. Mech. -Engl. Ed. 31(10), pp. 1217-1230] has some major flaws. We show that the results included in the paper by Zueco and Ahmed (2010) are incorrect both from a theoretical and practical point of view.

Key words: Magnetohydrodynamic (MHD), induced magnetic field, heat source, magnetic Prandtl number.

INTRODUCTION

In the paper "Combined heat and mass transfer by mixed convection magnetohydrodynamic (MHD) flow along a porous plate with chemical reaction in presence of heat source" by Zueco, J. and Ahmed, S., 2010, [Appl. Math. Mech. -Engl. Ed. 31(10), pp. 1217-1230], the steady mixed convective magnetohydrodynamic (MHD) flow of an incompressible viscous electrically conducting fluid past an infinite vertical porous plate taking into account the induced magnetic field has been studied. Results have been presented for the case of air at 20°C with Prandtl numbers of 0.71. However, there are fundamental errors in this paper and the presented results do not have any practical value. This argument is explained below:

(1) On page number 1219, it is assumed that “the magnetic Prandtl number is greater than the Hartmann number” but in Figures 2, 4 and 5, Prandtl number (Pr_m)= Hartmann number (M)=0.1 and in Figures 6 to 9, M > Pr_m (M=0.25, 0.5 and 0.75 while Pr_m =0.1), which are conflicting with its original assumption.

(2) On page number 1223, it is mentioned that "since Ec < 1 for all the incompressible fluids". However, on page number 1227 to 1228, the values of Ec are taken 0.5, 1.0 and 1.5 in Figure 8.

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(3) The important new thing in this work is the assumption that the electrically conducting fluid induces a new magnetic field, however, the importance of the induced magnetic field depends on the magnetic Reynolds number which is defined as follows (Davidson, 2006):

$$R_m = \mu\sigma u l\,, \qquad (1)$$

where, μ is the magnetic permeability, σ is the fluid electrical conductivity, u is the characteristic velocity of the flow, and l is the characteristic length scale. When the magnetic Reynolds number is much smaller than unity ($R_m << 1$) the induced magnetic field is negligible and the imposed external magnetic field is unaffected by the moving conducting fluid (Davidson, 2006).

In most laboratory experiments or industrial processes R_m is very low, usually less than 10^{-2} (Knaepen et al., 2003). In contrast, when the magnetic Reynolds number is equal to or greater than unity ($R_m >> 1$) the induced magnetic field is important and should be taken into account. Indeed certain applications, such as advanced schemes for the control of magnetogasdynamic flows around hypersonic vehicles, involve values of R_m of the order 1 to 10 (Knaepen et al., 2003).

In the above work, the authors took into account the induced magnetic field without any reference to the magnetic Reynolds number which is the one of the suitable criterion otherwise. Let us calculate here R_m for air at 20°C. Air electrical conductivity at 20°C is 3×10^{-15} to 8×10^{-15} $\Omega^{-1}m^{-1}$ (Pawar et al., 2009), whereas air magnetic permeability is 1.257×10^{-6} Vs /Am, (Magnabosco et al., 2006). For a typical velocity u =1.0 m/ s and a typical length scale l=0.1 m, the magnetic Reynolds number (dimensionless) is:

$$R_m \cong 3.8\times 10^{-22} \qquad (2)$$

Instead of using the above magnetic Reynolds number, the authors used the parameter Pr_m named as Magnetic Prandtl number (dimensionless) (Sharma, 2012),

$$\mathrm{Pr}_m = \sigma\mu\nu\,, \qquad (3)$$

Where, ν is the fluid kinematic viscosity. All the presented results are for air corresponding to Pr_m =0.1 to 2.

Let us calculate the Pr_m for air at 20°C. The air kinematic viscosity at 20°C is 1.827×10^{-5} m^2/s (Hughes and Young, 1966) and we have

$$Pr_m \cong 6.9\times10^{-16} \qquad (4)$$

CONCLUSION

For the fluid (air), the magnetic Reynolds number as well as the magnetic Prandtl number is very small and completely different from the values used in the results. Air cannot induce a significant magnetic field and the results presented in the paper under consideration do not have any practical value. Taking the above arguments into perspective, it is clear that the results included in the paper by Zueco and Ahmed (2010) are wrong both from a theoretical and practical point of view.

Conflict of Interest

The authors have not declared any conflict of interest.

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