Materials Research Proceedings 31 (2023) 550-563 https://doi.org/10.21741/9781644902592-57

Recycling of machining waste fibers in the formulation of new concrete

Salima TAFRAOUI[1,a], Ahmed TAFRAOUI[1,b*]and Naima SEGHOUANI[1,c]

[1] Laboratoire de Fiabilité du Génie MécaniqueBP 417 route de Kenadsa, Bechar Algeria

[a]tafraoui.salima@univ-bechar.dz, [b,*]tafraoui.ahmed@univ-bechar.dz, [c]tafraatt@yahoo.fr

Keywords: UPFC, Resistance, Metallic Fibers, UHPC, Dune Sand, Silica Fume

Abstract. The use of waste fibers from the mechanical machining of parts in the formulation of new concretes is of great importance for the protection of the environment because, on the one hand, it makes it possible to recover the materials already used and to on the other hand, it allows nature to be protected from excessive exploitation of the reserve of artificial metallic fibers. The new concretes have high performance (high compressive strength, low porosity and permeability, durability, etc.), however these concretes are fragile and have low tensile strength, which limits their use. The objective of this study is to see the influence of the introduction of waste fibers on the behavior of new concretes. It is necessary to study the physical-mechanical characteristics of these concretes composed of these wastes in the hardened state.

1. Introduction

Concrete has always been considered the most widely used construction material in civil engineering works. UHPC are materials with a cementitious matrix, with compressive strength. These materials are supplemented with metal fibers (UPFC) in order to obtain a ductile behavior in tension.

Indeed, the mechanical performance of UHPC or UPFC encourage their use in various fields such as mechanics and civil engineering, the absence of large aggregates in UHPC makes it possible to produce very thin facing elements with a thickness of 15mm.

Fibers from machining waste are chosen for reasons of availability and economy, come from a renewable source and can be integrated in a rational way in the field of construction. The objective of this work is to contribute to the recovery of the resource, which are the fibers of machining waste thanks to their low cost and their availability. In this pretext, we thought of the use of fibers from machining waste, as concrete reinforcements.

2. Materials and Methods

2 .1 Materials used

- CPJ 42.2 cement from the GICA cement plant in Bechar (Algeria)
- Dune sand from the Taghit region (Bechar Algeria)
- Fumed silica
- Crushed Quartz
- Admixtures: sikaViscoCrete 522 RMX (super-plasticizer)
- Drinking water
- Machining metal fibers.

2.1.1 Cement

UHPC are materials with a very low W/C (water/cement) ratio. Consequently, the rheology of UHPC is closely linked to the reactivity of the cement used.

We have thus seen that, from the point of view of chemical composition and rheology, cements with a low C_3A content and a low specific surface area give the best results [8]. They have a lower water demand.

The cement used in this research is Portland cement (Mâtine, GICA companyBéchar), (CPJ - CEM II/B 42.5) gray cement for high performance concrete intended for the construction of engineering structures (bridges, viaducts, tunnels, etc.), the chemical and physical characteristics of which are presented respectively in Table 1 and Table 2.

Table 1. Chemical composition in % of materials used

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	Fire loss
Cement	20,70	4,75	3,75	62,92	1,90	0,09	0,19	1,98	3,00
fumed silica	>95,00	-	-	-	-	0,60	-	-	-
Crushed Quartz	98,50	7500 ppm	450 Ppm	300 Ppm	-	-	5500 ppm	-	0,20
Dune sand	97,33	0,83	0,24	0,07	0,41	0,09	0,04	0,18	0,40

Table 2: The physical characteristics of the materials used

	Cement	fumed silica	Crushed Quartz	Dune sand
specific surface (cm^2/g)	3390	230000	6900	115
Average size D50(µm)	-	0,1	28	250
Actual density	3,16	2,24	2,65	2,65
Water absorption coefficient (%)				0,15

2.1.2 Additions

• **Silica fume**

The silica fume used in this work is a gray powder (rather dark), marketed under the name of Condensil S95 DM (Sika company), and derived from the ferro-silicon manufacturing industry. Its chemical and physical characteristics are given in Table 1 and Table 2 respectively.

Figure 1: Silica fume

• **Crushed quartz**

The crushed quartz used for the formulations undergoing heat treatment is marketed under the name MILLISIL C400 by the Sifraco Company. The physical and chemical characteristics are given in Table 1 and Table 2.

• **Dune sand**

According to the bibliographical research, and the physico-chemical analysis, the quartz sand of the dune of the western erg of the region of the south-west of Algeria is promising in the

Materials Research Proceedings 31 (2023) 550-563 https://doi.org/10.21741/9781644902592-57

formulation of UPFC. However, for practical reasons supply data t in Table 1 and Table 2 respectively.

Absolute density according to the Standard [NFP 18-301]
This test is defined as being the mass per unit volume of the material that constitutes the aggregate without taking into account the voids that may exist between the grains (Figure 3).
The absolute density is determined by the following formula:

$$\rho = \frac{M}{V_2 - V_1} \qquad (1)$$

With:
ρ: Absolute density
M: Mass of solid grains
V_1: Volume of water
V_2: Total volume (solid grains + water).

Apparent density according to the Standard [NFP 18-554]
The apparent density is defined as being the mass of the unit of apparent volume of the body, that is to say that of the volume constituted by the matter of the body and the voids it contains. The apparent density is determined by the following formula:

$$\rho_d = \frac{\text{Mass of dry aggregate}}{\text{Container volume}} = \frac{M_1 - M_0}{V} \qquad (2)$$

With:
V: Volume of the container
M_0: Mass of the clean and empty container
M_1: Mass of the filled container

Sand equivalent according to the Standard [NFP 18-598]
This test makes it possible to measure the cleanliness of the sand. It gives an overall account of the quantity and quality of the fine elements, by expressing a conventional volumetric ratio between the sandy elements which sediment and the fine elements which flocculate.
The value of the equivalent of sand (ES) is the multiple ratios by 100, of the height of the sediment sandy part on the total height of the flocculate. The formula that allows the determination of the sand equivalent is:

$$ES = \frac{h_1}{h_2}\ 100\% \qquad (3)$$

With:
h_1: clean sand + fine elements
h_2: clean sand only
The physical characteristics of the sands at the end of the tests are shown in Tables 3.

Table 3: Physical characteristics of dune sand (0/2)

Features	Results	Unit
Apparent volumetric mass	1.56	[gr/cm^3]
Absolute Density	2.50	[gr/cm^3]
Sand Equivalent (NF EN 933-8)	91.22	[%]

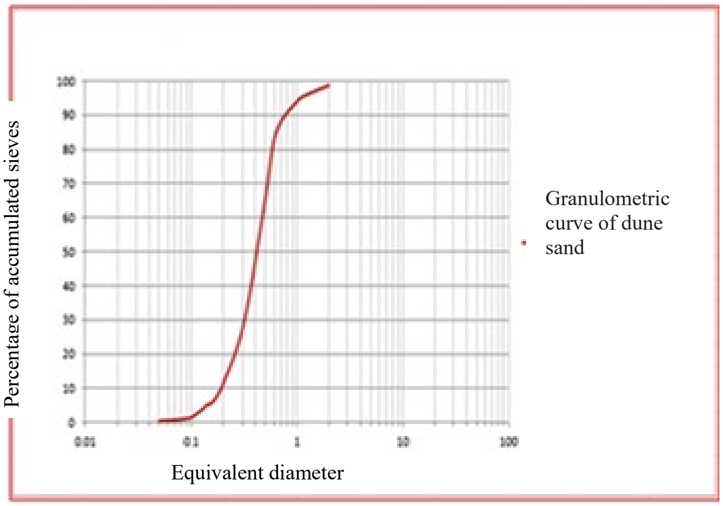

Figure 3: Granulometric curve of dune sand

- **Water**

The water used to make the mortars is drinking water from the network.

- **Additive**

The super high water-reducing plasticizer used during this study. This is a super plasticizer, in accordance with standard NF EN 934-2 [29], based on acrylic copolymer of new generation, non-chlorinated and intended for the prefabrication industry.

- **Fibers**

The fibers selected for this study are metallic steel machining fibers, 13 mm in length and 160 µm in diameter (Figure 4)

Figure 4: Machining metal fibers (length 13 mm, diameter 160 µm)

Materials Research Proceedings 31 (2023) 550-563 https://doi.org/10.21741/9781644902592-57

2.2 Experimental methods

2.2.1 Formulation

Table 4: Formulation of UHPC with dune sand (noted DS) (kg/m^3)

	UHPC with Silica Fume	
	CDSF	CDSFCQF
Cement	828	691
silica sand	911	759
fumed silica	207	172
Crushed Quartz	0	276
Metallic fibers	0	138
Super plasticizer	26,4	22,0
water efficient	224,6	187,3
Volumic mass (kg/m^3)	2153	2363
W/C	0,27	0,27
SF/C%	25	25

With:
CDSF: Concrete with Dune (SD), and Silica Fume (FS)
CDSFCQF: Concrete with Dune, Silica Fume, Crushed Quartz and Metal Fiber

2.2.2Mortier Ordinaire

- **Materials used**
- ✓ CPJ 42.2 cement from the GICA cement plant in Béchar (Algeria)
- ✓ Oued lakhdar sand from the Béchar region (Algeria)
- ✓ Laboratory drinking water
- ✓ The use of metal fibers to increase ductility.

The physical characteristics of dune sand (0/3) at the end of the tests are represented in table 5

Table 5: Physical characteristics of dune sand (0/3)

Features	Results	Unit
Apparent volumetric mass	1.53	[gr/cm^3]
Absolute Density	2.7	[gr/cm^3]
Sand Equivalent (NF EN 933-8)	77.65	[%]

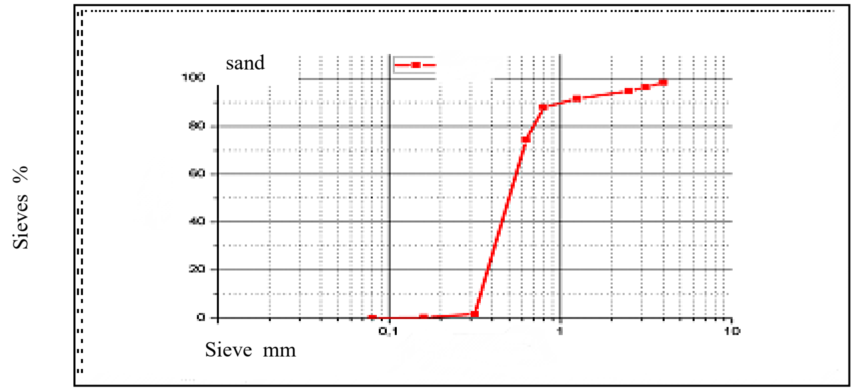

Figure 5: Particle size analysis of sand (0/3)

- **Formulation and conservation of test specimens**

The formulation of fiber-reinforced mortars (5% of metal fibers) for 3 test specimens (40x40x160) made up is shown in the following table:

Table 6: Formulation of a fiber mortar

component	Cement(g)	water(ml)	Sand(g)	metal fibers(g)
M0	450	225	1350	135

- **The mixingmethod**

Mixing plays a valuable role in the manufacture of mortars, hence the need to master and respect its mode and time, as shown in Table 7:

Table7: Formulation and mixing sequence

Materials	Mixing sequence
cement +water	Mixing Materials 30s (Slow Speed)
Sand	Added sand for 30s (slow speed) and 30s (fast speed)
Metallic fibers	Possible introduction of fibers and mixing for 1 minute
W/ C= 0.5	Stop the mixer for 30s Resume mixing for 1min (fast speed)

- **Filling and conservation of molds**

The filling and conservation of the molds is carried out as follows:

✓ After mixing, one proceeds to the filling at the rate of two layers, in metal molds which were coated with oil in advance.
✓ One proceeds to the vibration with the vibrating table for the two layers; the total duration of vibration 10s (5s for the first layer and 5s for the last)
✓ Level and smooth the surface of the concrete with a trowel
✓ The preservation of the molds containing the test specimens is done in the laboratory, and in order to avoid any Initial desiccation, the molds are protected with plastic film
✓ After 24 hours the specimens are removed from the mold, recorded and immersed in a basin of water until they are 60 days old (Figure 6).

Figure 6: Casting of specimens

2.2.3 Behavior when fresh

2.2.3.1 Spreading and flow test

The spreading test is carried out using the Abrams mortar cone. The spread and flow values measured for the two formulations are presented in Table 8. Figure 7 gives an illustration of the spread obtained in shape and color.

Table 8: Rheological results of UPFC

Samples	CDSQF	CDS
Spreads in cm	45	50

Figure 7: UHPC spread with fumed silica

CDSQF: concrete with sand dune fumed silica, quarter crushed and metallic fiber
CDS: concrete with dune sand and fumed silica

We note that the spread of CDS concrete is between 48 and 52 cm, with the same water and admixture content, the UHPC with fiber have spreads of between 42 and 46 cm.

Regarding the effect of sand type on workability, there is greater fluidity with dune sand. This is certainly to be linked to the slight differences in shape and size of the grains which have an influence on the friction with the fibers and therefore on the flow. It can be deduced from this that the use of dune sand will be beneficial with regard to the installation of UHPC.

We did not find excessive heterogeneous fiber distributions. This can be explained by their small size of the fibers (13 mm) and the limited friction generated with aggregates that are also small in size.

2.2.3.2. Flow test on workability

The flow time measured on mortar workability was about 2 seconds according to the standard (NFP 18-452) [34] for all the formulations studied.

This very short delay reflects a significant fluidity of our materials without being able to distinguish any influence of the type of fines or sand on the flow, contrary to what had been noted during the spreading test. The UHPC studied have a rheological behavior similar to that described by Bonneau [8]. They are easy to mold materials and well suited for prefabrication. They can be used to produce shapes of varying complexity and achieve excellent detail reproduction due to their fluidity and bubble-free surface quality.

2.2.3.3. Measurement of the amount of entrained air

The quantity of entrained air for all the formulations studied in the fresh state is between 1.8% and 2.0% respectively for the samples with fibers and without fibers. These values are of the same order as those of ordinary concretes. They also correspond to the orders of magnitude of the values measured on UPFC by Rougeau (3%) [35] and the BPR200 by Roux et al (1%) **[36]**.

2.2.3.4. Determination of bulk density and porosity

We note that the apparent densities of our materials are almost identical. On the other hand, a slight difference in porosity is observed between the concretes incorporating fiber (average of 6.3%) and those which do not have fibers.

(6.0%). The greater amount of void in fiber UHPC, and the higher density of this ultrafine Silica fume, at the same dosage, could explain the fact that the densities are almost equivalent (Table 9).

Table 9: Bulk density and porosity

Samples	CDSQF	CDS
Apparent Density (g/cm3)	2,382	2.361
Porosity (%)	6,3	6.0

2.2.4. Behavior in hardened state

2.2.4.1 Compressive strength

The UHPC compressive strength results correspond to the average of 2 tests carried out on the two pieces of the 3 prismatic specimens (40x40x160 mm) tested beforehand in bending. They are presented in Table 10 for the 4 maturities of 1, 7, 14 and 28 days.

Table 10: Mechanical compressive strengths of the different compositions

Samples	CDS	CDSQF
Time(days)	Compressive strength in MPa	
1	19.68	27.49
7	76.76	52.60
14	83.47	56.79
28	85.73	73.90

From the expiry of 7 days, the concrete with fiber exceeded the concrete without fibers 8 MPa of compressive strength. At 28 days, the concrete without fibers exceeded the concrete with fibers, the maximum mechanical strength that is 85.73 MPa.

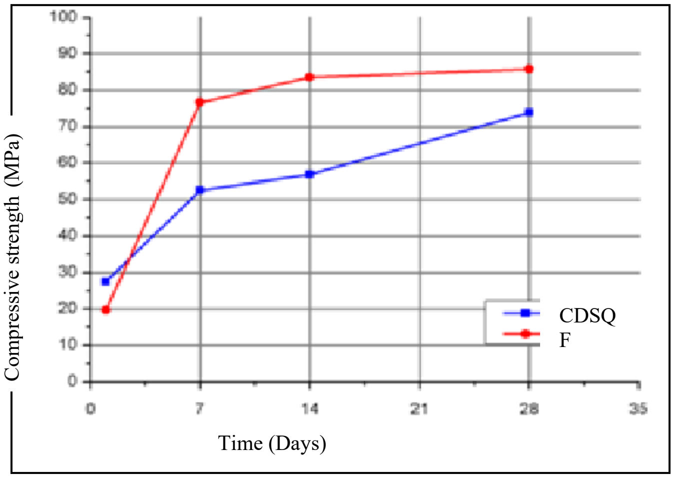

Figure 8: Hardening kinetics of the different fiber UHPC studied

Figure 8 shows the kinetics of compressive strength evolution for the different concretes (with the Eurocode 2 notations [26],fcm average strength at 28 days and fcm(t) average strength at time(t).

The analysis of the kinetics of the resistances in compression highlights the differences between the UPFC.

Concrete with dune sand (CDS and CDSQF), concrete with fibers in 24 hours is the most resistant, compared to the 3 deadlines 7,14,28 because the mixing problems and the addition of water reduce the resistors.

2.2.4.2 Bending strength

Table 11 presents the results of the mechanical bending tests as a function of the age of the material obtained for the UHPC studied according to standard NF EN 12390-5 [32] on 40×40×160 mm specimens. These bending resistances are calculated from the maximum force applied by the press.

Table 11: Mechanical resistances in bending of the various compositions at various deadlines

Samples	CDS	CDSQF
Time(days)	bending strength in MPa	
1	3.76	4.01
7	5.55	6.34
14	7.94	7.27
28	8.10	7.79

The concretes studied show similar flexural strength values, regardless of the end of the test. The most significant differences appear at 1 day (values between 3 and 4.01 MPa). At 28 days, the strengths are slightly higher than 7 MPa.

Comparisons with the results of the literature require careful reading because the formulations, type of cure and heat treatment vary according to the studies carried out on these new materials. Thus, it can be estimated that the bending strengths can evolve between 7 MPa. One of the main reasons for this wide range of values is most likely the type (geometrical and mechanical characteristics) and quantity of fibers used.

Figure 9 presents the evolutions of the flexural strengths at the normalized instant compared to their values at 28 days.

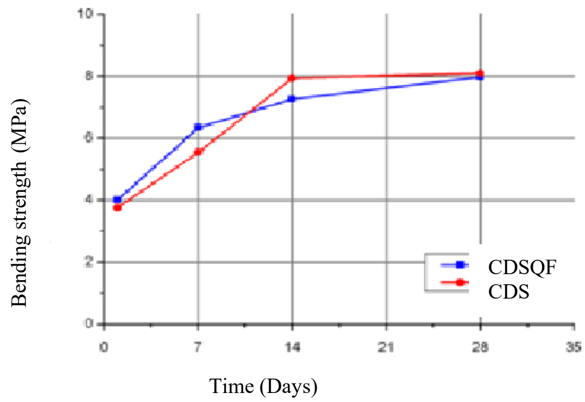

Figure 9: Kinetics of evolution of the flexural strength of the different formulations

The concretes with dune sand (CDS and CDSQF), the concrete with the fibers in 24h and 7days it was the most resisted, against for the deadlines 14.28 because the problems of mixing and the addition of water decrease resistance.

From the results of the bending tests, the tensile strength can be deduced. Indeed, the bending test is relatively simpler to implement than a direct tensile test. The AFGC [27] proposes, on the basis of the approach of the CEB-FIP calculation code, to evaluate the tensile strength from the results of the bending test on a prismatic specimen not notched by the intermediary of the following formula to take account of the scale effect.

$$R_t = R_{fl} \cdot \frac{2{,}0 \cdot \left(\frac{h}{h_0}\right)^{0{,}7}}{1 + 2{,}0 \cdot \left(\frac{h}{h_0}\right)^{0{,}7}} \qquad (4)$$

With
R_t: Tensile strength due to bending (MPa)
R_{f1}: Bending strength (MPa)
h: Height of the prism (mm) and h_0 = 100 mm

The bending strength R_{fl} is equal to the value of the fiber tensile stress lower than mid-span, calculated from the value of the applied force F_{fiss} corresponding to the loss of linearity of the elastic behavior. Unfortunately, the test device of the press used did not allow us to set up a deflection sensor. The exploitation of the tensile strengths by bending cannot therefore be carried out, for lack of precise evaluation of the force F_{fiss}. The breaking force indicated by the press is obviously greater than this value.

If we apply the formula taking into account the geometry of our specimens, we see that the scale effect coefficient is equal to 0.51. This therefore means that the tensile strength is less than half of the measured bending strength. One could therefore estimate with restraint that the tensile strengths are approximately in a range between 4 and 8 MPa, values significantly higher than those of common concretes.

2.2.5 The results of the fiber-reinforced mortar in compressive

Table 12: Mechanical compressive strengths of Mortar and UPFC

Samples	Fiber mortar	CDSQF
Time(days)	Compressive strength in MPa	
1	7.32	27.49
7	14.35	52.60
14	23.83	56.79
28	30.37	73.90

From the expiry of 1 day, the UHPC exceeded the fiber mortar 20 MPa of compressive strength. At 28 days, the UPFC exceeded the Fiber Mortar more than 40 MPa of compressive strength, the maximum mechanical strength of Fiber Mortar is 30 MPa.

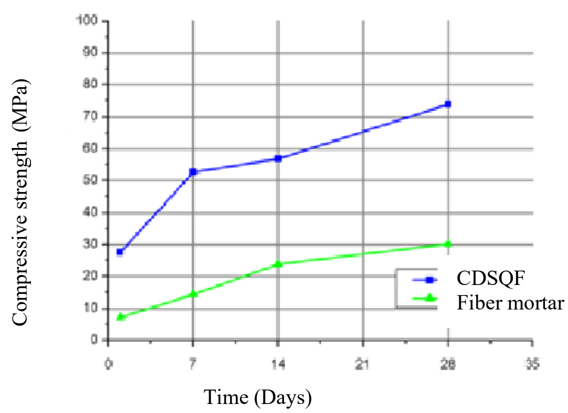

Figure 10: Mechanical compressive strengths of Mortar and UPFC

Note that concrete with dune sand (CDSQF) is more resistant than fiber mortar in the 4 deadlines 1, 7, 14, 28.

2.2.6 The results of the fiber-reinforced mortar in bending

Table 13: Mechanical resistances in bending of Mortar and UHPC

Samples	Fiber mortar	CDSQF
Time(days)	Bending resistance in MPa	
1	1.53	4.01
7	2.41	6.34
14	4.01	7.27
28	5.33	7.79

From the expiry of 1 day, the UHPC exceeds the Fiber Mortar more than 2 MPa of resistance in bending, the same superiority at 28 days for UHPC. The maximum mechanical strength of UHPFR exceeded 7 MPA.

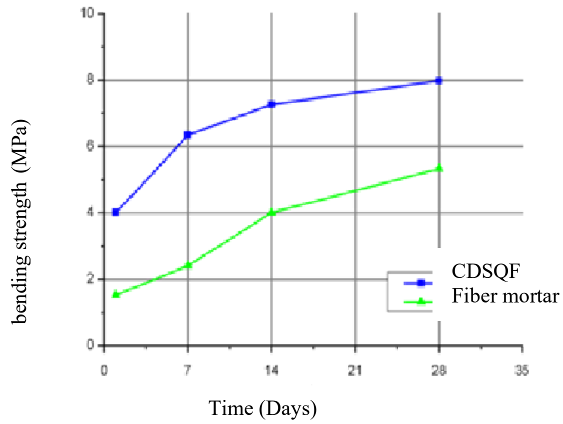

Figure 11: Mechanical resistances in bending of Mortar and UHPFRC

Deduce that the fiber mortar is less resistant for the 4 maturities than the CDSQF.

3. General conclusion

The use of artificial metal fibers as reinforcements in new concretes (UHPC) has impacts on the environment. In this case, we have chosen fibers from machining waste to reduce the problem of excessive exploitation of the reserve of metal fibers.

According to the results of the tests on the various UHPC specimens reinforced with machining waste fibers in 24 hours it was the most resistant compared to the specimens without fiber, on the other hand for the 3 deadlines 7, 14, 28 the specimens without fibers they are more resistant than UPFC because the problems of mixing and the addition of water to decrease the resistances.

The incorporation of machining waste fibers in the ordinary mortar made it possible to increase its resistance to bending relatively if looking at the results obtained in UHPC. We added the mill waste fibers into the regular mortar to see how active it is in the regular mortar and if it has any other adaptation or other UPFC results.

The perspective of using fibers from machining waste in the field of Civil Engineering has allowed us to contribute in a rather humble way to the recovery of these materials.

The addition of machining waste fibers in UHPC and ordinary mortar modifies the behavior of concrete and considerably improves the mechanical characteristics of the material. The experimental results show an efficiency of the fibers for bending stresses, an improvement in the resistance to bending and compression.

The properties of new concretes are not influenced by the length, dosage and treatment of fibers only but with other factors such as aggregates, cement and fillers.

Acknowledgments

The authors wish to thank the Directorate General for Scientific Research and Technological Development (D.G.R.S.D.T., Algeria) for financial support of this work. Thanks to the professors and students members of Laboratory of Eco-Materials: Innovations & Applications (EMIA ex. LFGM).

References

[1] A.Picon,The art of the engineer, Editions du Center Georges Pompidou, Paris ISBN 2-85850-911-5, 1997, p. 311.

[2] Sablocrete, Characteristics and practices of use, Sablocrete, National Research and Development Project, Presses of the National School of Bridges and Roads, Edition Lavoisier, 12/1994, p.236.

[3] D.M.Roy, Gouda G.R., High strength generation in cement pastes. Cement and ConcreteResearch,vol.3,no.6,1973,p.807-820. https://doi.org/10.1016/0008-8846(73)90013-6

[4] H.H.Bache, Densified cement/ultrafine particle-based materials. 2nd international conferenceonsuperplasticizersinconcreteOttawa,Canada,june10-12,1981.

[5] P.Richard, M.H.Cheyrezy, Composition of reactive powder concretes. Cement and Concrete Research,vol.25,no.7,1995,p.1501-1511. https://doi.org/10.1016/0008-8846(95)00144-2

[6] A.Tafraoui, Doctoral thesis, contribution to the recovery of dune sand from the accidental erg, University of Toulouse 13feb 2009 .

[7] M.Cheyrezy, Structural applications of BPR. AFPC-AFREM Conference on High Performance Concretes and Ultra High Performance Concretes, INSA Lyon, June 3, 1998.

[8] O.Bonneau, Study of the physico-chemical effects of superplasticizers in order to optimize the rheological behavior of Ultra High Performance concretes. Doctoral thesis, Department of Civil Engineering, University of Sherbrooke, Quebec, Canada, 1997.

[9] AFNOR,NFEN12620 ,Aggregates for concrete, AFNOR, Classification index: P18-601, August 2003.

[10] AFNOR,XPP18-545,Aggregates Elements of definition, conformity and codification AFNOR, February 2004.

[11] A.M Neville, Properties of concrete. Fourth Edition, England: Longman Edition, 1995, p844.

[12] AFNOR, NF EN 13263-1(Classification index: P18-502-1), Silica fume for concrete. Part 1: definition, requirement and compliancecriteria, September 2005.

[13] P.Rossi, S.Renwez, A.Belloc, Ultra High Performance fiber-reinforced concretes. Liaison bulletin from the central laboratory for bridges and roads, no.196, March April 1995, p. 61-66.

[14] AFGC,Ultra-high performance fiber-reinforced concretes. Interim Recommendations, January 2002.

[15] M.Behloul, Definition of a BPR behavior law. Annals of the ITBTP, no.532, March-April 1995, p. 122-127.

[16] M.Alpardi, Admixtures used to enhance placing characteristics of concrete. Cement and concrete composites,vol.20,no2/3,April-June,1998,p.103-112 https://doi.org/10.1016/S0958-9465(98)00071-7

[17] J.Dugat, N.Roux, G.Bernier, Experimental study of the deformation under stress and the fracture behavior of reactive powder concrete (RPC). Annals of the ITBTP, n°.532, March-April 1995, p. 112-121.

[18] S.Alpardi, R.Coppolla, R.Troli, M.Alpardi, Mechanical properties of modified reactive powder concrete.Proceedings,5thCANMET/ACI international conference on superplasticizer and other chemical admixtu resin concrete,SP-173,Rome,Italy,1997,p. 1-21.

[19] P.Rossi,S.Renwez,F.Guerrier,Ultra High Performance fiber-reinforced concretes.

[20] The current experience of LCPC, Bulletin des Laboratoires des Ponts et Chaussées, no.204, July August 1996, p.87-95.

[21] G.Lim, S.Hong, Slump loss control of cement paste by adding polycarboxylic types lump-releasing dispersant. Cement and Concrete Research,vol.29,1999,p.223-229. https://doi.org/10.1016/S0008-8846(98)00188-4

[22] E.Hanna, K.Luke, D.Perraton,P.C.Aitcin, Rheological métakaolin of Portlandcementinthepresenceofasuperplasticizer,Proceedings3rdInt.Conferenceonsuperplasticizers and other chemical admixtures in concrete. SP-119, Ottawa, Canada, 1989, p.171-188.

[23] G. DREUX,J. FESTA, New concrete guide, Seventh Edition Eyrolles, 1995.

[24] S. MOHELLEBI, Characterization and Modeling of the physico-hydro mechanical parameters of a lightweight concrete based on composite aggregates, Doctoral thesis, Mouloud Mammeri University of Tizi-Ouzou Algeria.

[25] Technical sheets Volume 2, Concretes: formulation, manufacture and implementation, information center on cement and its applications, January 2013.

[26] Y.Fritih, Contribution of a reinforcement of Fibers on the behavior of reinforced self-placing concrete elements, Doctoral Thesis, University of Toulouse, July 08, 2009.

[27] Eurocode2, EN1992-1-1,General rules and rules for buildings, Part 1-1. October 2005.

[28] AFNOR, NF P 18-342, Admixtures for concrete, mortar and grout - Part 2: Admixtures for concrete - definitions and requirements, Sept 2002.

[29] F.DeLarrard, T.Sedran, A new approach to concrete formulation. Annals of building and public works, no.6 p. 39-54, December 1999.

[30] AFNOR, NF EN 934-2/A2, Admixtures for concrete, mortar and grout-Part 2: admixtures for concrete-Definitions, requirements, conformity, marking and labelling, AFNOR April 2006.

[31] K.Ozawa, N.Sakata, H.Okamura, Evaluation of self compatibility of fresh concrete using the Funnel test. Concrete Journal of JSCE, no.25, June 1995.

[32] AFNOR, NF P 18-452, Concretes Measurement of the flow time of concretes and mortars with workability meters, May 1988.

[33] AFNOR, NF EN 197-1,Cement - Part 1: Composition, specifications and conformity criteria, February 2001

[34] AFPC-AFREM, Durability of concretes: Recommended methods for measuring the quantities associated with durability, Report of Technical Days LMDC, INSA-UPS, Toulouse. December 1997.

[35] AFNOR, NF P 18-452, Concretes - Measurement of the flow time of concretes and mortars with workability meters, May 1988.

[36] P. Rougeau, D.Boulet, M.Shink, Ultra High Performance concretes Synthesis of knowledge and feasibility study on laboratory prototype, CERIB document DDI 002, 2000.

[37] N.Roux,M.Barranco,Implementation of reactive powder concretes in the construction industry, Annales de L'ITBTP, no.532, 1995.