Visual Abstract

Effect of date palm and polypropylene fibers on the characteristics of self-compacting concrete: comparative study

Dounia Derdour, Mourad Behim, Mohammed Benzerara
Materials, Geomaterials and Environment Laboratory (LMGE), Faculty of Technology, Department of Civil Engineering, Badji Mokhtar- Annaba University, P.O. Box 12, 23000, Annaba, Algeria
douniaderdour@hotmail.com; dounia.derdour@univ-annaba.dz
mbehim@yahoo.fr; mourad.behim@univ-annaba.dz
mohammed.benzerara@yahoo.com; mohammed.benzerara@univ-annaba.dz

ABSTRACT. This article presents the results of a comparative experimental study on the influence of date palm fibers to replace polypropylene fibers used as reinforcement in self-compacting concrete (SCC). Indeed, the use of polypropylene fibers makes it possible to reduce the plastic shrinkage of concrete. Date palm fibers have mechanical characteristics (tensile strength and elasticity modulus) largely sufficient to replace polypropylene fibers. The use of natural fibers has several advantages, they are natural, renewable, have no effect on the environment and require little energy for their transformation unlike synthetic fibers. In this comparative study, polypropylene fiber is used as a control material and date palm fiber as a study material. The results obtained show that the two types of fibers decrease the fluidity and the compressive strength, increase the flexural strength and decrease the shrinkage. Date palm fibers delay the appearance of cracks more than polypropylene fibers. Date palm fibers guarantee the best results of SCC in fresh and hardened state.

KEYWORDS. Self-compacting Concrete, Fibers, Workability, Mechanical behavior, Shrinkage, Environment.

OPEN ACCESS

Citation: Derdour, D., Behim, M., Benzerara, M., Effect of date palm and polypropylene fibers on the characteristics of self-compacting concrete: comparative study, Frattura ed Integrità Strutturale, 64 (2023) 31-50.

Received: 15.10.2022
Accepted: 12.01.2023
Online first: 15.01.2023
Published: 01.04.2023

INTRODUCTION

The use of plant fibers as reinforcement in building materials has existed for a long time. Raw earth bricks reinforced with straw are an example. However, the transition from the traditional clay matrix to the cement matrix is relatively recent, yet plant fibers are locally available, renewable, less polluting [1–7] and require little energy for their transformation compared to synthetic fibers [8–12]. The reinforcement of mortars and concretes with fibers dates back to the beginning of the 19th century [13] and the use of vegetable fibers in these materials dates back to the seventies of the 19th century, when the first works aimed to replace asbestos fiber in the elements prefabricated [14]. Since then, many studies have been conducted on the use of plant fibers in cement matrix [15–18]. These works fall within the context of

sustainable development and are encouraged by Brundtland report [19] on the preservation of non-renewable natural resources. The most studied natural fibers, with the aim of replacing synthetic fibers in concretes and mortars are flax (linen) [20,21], bamboo [17], coconut [22,23] and hemp fibers [24]. Other natural fibers have also been studied, notably straw, sisal, jute, bagasse…etc. [25–31]. In Algeria, studies on the use of plant fibers in concrete and mortar are recent. These works concerning vegetable fibers that are available in Algeria such Diss [1,4–7], Alfa [7,32–34] and date palm fibers [4,7,35,36]. The number of date palms of different species is estimated at 18 million feet in Algeria, cultivated over an area of 165,000 hectares [4,37], generating more than 200 tons of waste deposited in landfill or burned [4,36].
In our study which aims at the elaboration of self-compacting fiber-reinforced concrete, we are interested in date palm fiber because it has asperities with significant roughness and interesting mechanical characteristics depending on varieties according to the regions of the date palm. Tensile tests measurement shows that date palm fibers presents an average tensile strength of 80-200 MPa, Young modulus of 2-10 GPa and elongation 2-10 mm [7,11,36,38,39]. It also has very significant water absorption, which limits cracking at a young age by reducing plastic shrinkage. The use of fibers in concrete makes it possible to confer a better resistance to the propagation of cracking, to reduce the fragility of the material, to improve the tensile strengths, to bending and to shocks as well as the improvement of ductility [11,35,40]. The objective of this study is the valorization of date palm fiber as reinforcement in self-compacting concrete. This is to replace the polypropylene fiber traditionally used. SCC is extremely fluid and its placement in the formwork does not require vibration [41]. This characteristic is obtained by using a super plasticizer, a large volume of paste varying from 300 to 400 (l/m³) limiting the quantity of coarse aggregates and their size [42], thus making them more susceptible to shrinkage [43] and cracking. Seven SCC are formulated, a reference SCC noted (RSCC) (without fibers), three control SCC with polypropylene fiber noted (PPSCC6, PPSCC9 and PPSCC12) and three study SCC with date palm fiber noted DPSCC6, DPSCC9 and DPSCC12). The fiber dosages are 600, 900 and 1200 g/m³. The results obtained on the PDSCC were compared with those obtained from the PPSCC in the fresh state (slump flow, filling ability and stability) and in the hardened state (compressive, flexural strength, shrinkage, and capillary water absorption). The use of date palm fibers in comparison with polypropylene synthetic fibers in SCC could constitute an interesting alternative on the environmental and the technic-economic levels.

MATERIALS USED AND EXPERIMENTAL METHODS

Materials: Cement

The cement used in this study is a compound Portland cement CPJ-CEM II 42.5 comes from the Hdjar Essoud cement plant (Skikda, eastern Algeria) resulting from a simultaneous grinding of clinker (80%), granulated slag (20%) and gypsum (5%) conforming to the standard NA 442 [44]. The physic-mechanical characteristics of cement is given in Tab. 1.

Characteristics	Units	Values
Apparent density	g/cm³	1.02
Absolute density	g/cm³	3.01
Normal consistency	%	28
Start of take	h/min	2/37
End of take	h/min	4/12
Refusal to the sieve 0.08 mm	%	5

Table 1: Physic-mechanical characteristics of cement [45,46].

Materials: Aggregates

Two sands are used in this study: a fine siliceous sand, coming from Ouargla region (eastern Algeria) and a quarry sand resulting from the crushing of limestone rocks from Skikda region. Two fractions of gravel used in this work: (3/8) and (8/16) resulting from the crushing of limestone rocks from Skikda. The physical characteristics of the study aggregates are shown in Tab. 2 and the particle size composition is represented by Fig. 1.

Characteristics	Units	Silica sand	Quarry sand	Gravel 3/8	Gravel 8/16
Apparent density (NF EN 1097-3)	kg/m³	1620	1690	1450	1590
Absolute density (NF EN 1097-3)	kg/m³	2590	2790	2700	2680
Fineness modulus (XP P 18-540)	%	1.89	3.09	/	/
Sand equivalent (NF EN 933-8)	%	89.7	88	/	/
Los Angeles test (P 18-573)	%	/	/	20	20
Micro Deval test (NF EN 1097-1)	%	/	/	9.29	9.29

Table 3: Characteristics of aggregates [47–51].

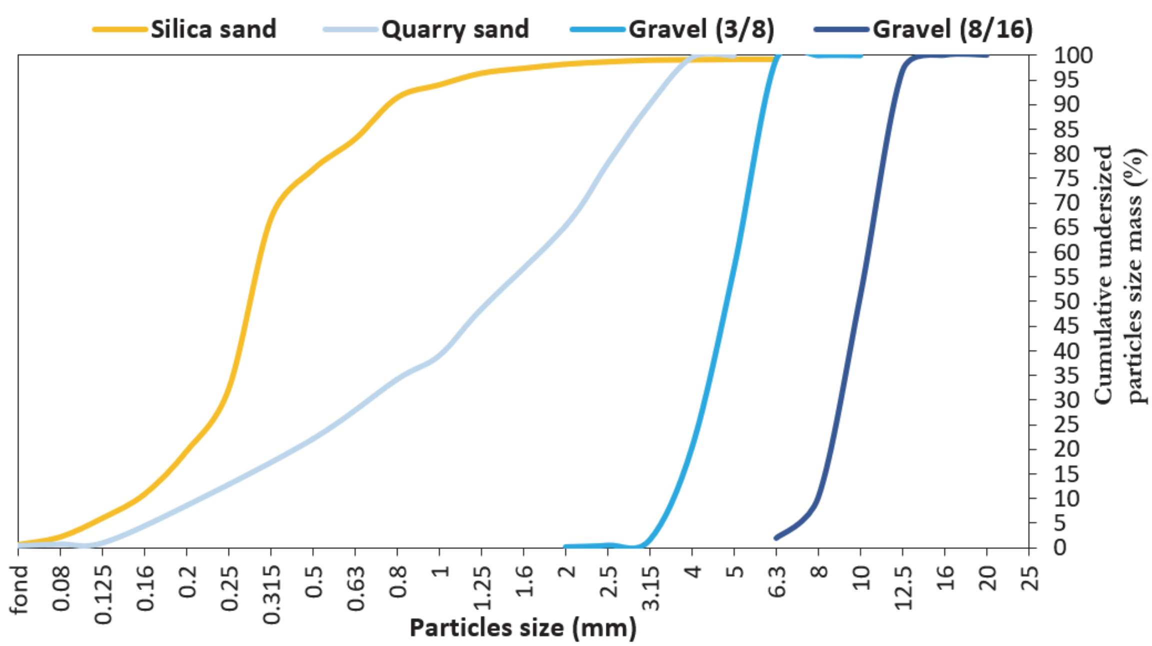


Figure 1: Granulometric curves of the aggregates used (NF P 18-560) [52].

Materials: Limestone Filler

The limestone filler used in this study is a calcium carbonate in powder form (derived from limestone rock waste and ground to a fineness greater than that of cement) with a $CaC0_3$ content equal to 98%. Its trade name is Bexcar 10N by SNC Bexcar Benbrahim in El-Khroub, Constantine (eastern Algeria). Tabs. 4 and 5 give the physical properties and chemical composition of the limestone filler used.

Elements	CaO	Al_2O_3	SiO_2	Fe_2O_3	MgO	Na_2O	Cl^-	K_2O	SO_3	P.A.F
Content (%)	55	0.11	0.50	0.06	0.20	0.08	0.27	0.01	0.06	42.5

Table 4: Chemical composition of limestone filler according to the producer.

Characteristics	Units	Limestone
Apparent density	kg/m³	790
Absolute density	kg/m³	2700
Fines content (refusal to the 0.08 mm sieve)	(%)	4.3
Blaine Specific Surface	(cm²/g)	

Table 5: Intrinsic characteristics of the limestone fillers used.

Materials: Adjuvant

The adjuvant used is a water-reducing plasticizer under the name "VISCCOCRETE 3045" manufactured by the Algerian company SIKA. It is non-chlorinated, ready-to-use adjuvant and based on modified poly-carboxylates, which comes in the form of a brown liquid. It makes it possible to obtain a long rheology maintenance (>1H30), whose physical and chemical characteristics are given in Tab. 6.

Adjuvant VISCCOCRETE 3045	
Physical state	Liquid
Color	Chestnut
Density	1.11±0.02
pH	5±1
Cl ion content	≤0.1%
Na_2O ion content	36.04±1.8%

Table 6: Physical and chemical properties of plasticizer used according to the producer [53].

Materials: Polypropylene fibers

The polypropylene fibers used are marketed by the Algerian company "SIKA" (Fig. 2). Polypropylene fibers are used as a control fiber in the composition of self-compacting concrete reinforced with polypropylene fiber (PPSCC). The technical characteristics of polypropylene fibers are given in Tab. 7.

Figure 2: Polypropylene fibers.

Characteristics	Units	Polypropylene fibers
Color	-	White
Diameter	µm	25 (±10%)
Length	mm	12 (±10%)
Density	g/cm³	0.91
Tensile strength	N/mm²	300-400
Fusion point	°C	160-170
ignition point	°C	570
Elongation	%	≥ 120
Number of fibers	per kg	120×10^6
Young's modulus	kN/mm	3

Table 7: Technical characteristics of polypropylene fibers used [54].

Materials: Date palm fibers mesh

The date palm fibers used in this study come from palm trees at Ouargla region (eastern Algeria). The fibers are naturally woven date palm surface fibers. They are formed by the superposition of three trellis plates. They are extracted from the trunk of the palm in plate form. The preparation of fibers consists of separating fibers pads into fibers, which are cut to the desired length as shown in Fig. 3. The cutting of the fibers is done in a shredder with parallel-cut knife mill. The length of the fiber depends on the shredding speed (adjustable) [55].

Figure 3: Preparation of date palm fibers mesh.

The length of the date palm fibers can be cut according to the need, in this study it is equal to that of the polypropylene fiber (12 mm). Date palm fibers are not uniform in diameter but it varies from 0.4 to 0.6 mm and the same fiber can have a diameter variation of 0.4 to 0.5 µm as shown in Fig. 4. Fibers diameters measurements were performed using optical microscope imaging (Fig. 5).

Figure 4: Measurement of date palm fibers diameter by optical microscope imaging.

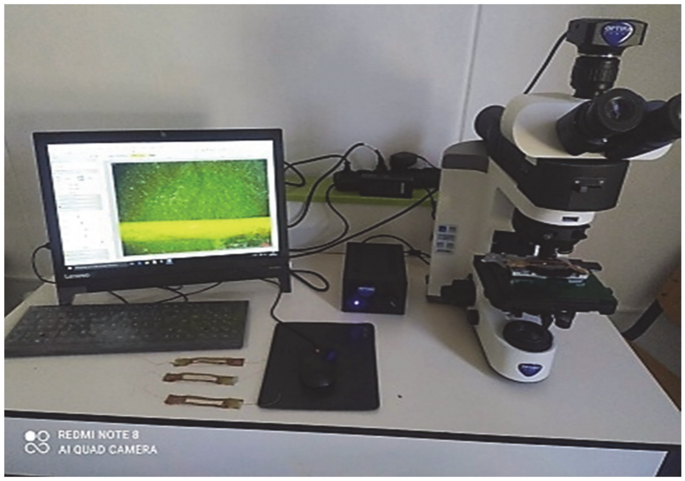
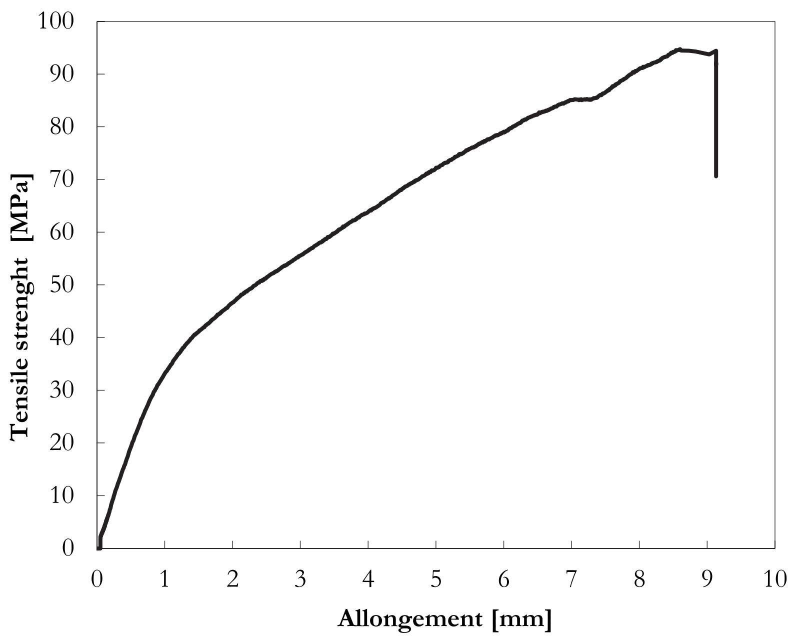


Figure 5: Optical microscope imaging used for measurement palm date fibers diameter.

The direct tensile test on the date palm fibers per unit, length of 60 mm was carried out using a ZWICK Roell press tensile machine with a maximum capacity of 20 kN (Fig. 6a). In our study, we followed the same protocol used by Benzerara, M. et al [4]. It is an experimental test protocol because there is no specific standard published.
The stress-strain curve is shown in Fig. 6b. The Tabs. 8 and 9 present respectively the physic-mechanical characteristics and chemical composition of fibers used.



(a) (b)

Figure 6: The direct tensile test on date palm fiber mesh: (a) loading device and (b) tensile curve.

The water absorption coefficient of date palm fibers was determined according to a procedure drawn from several works [1,7,35,36,56]. Besides the water absorption value at 24 hours, we also determined the absorption kinetics. Six fiber samples were dried in an oven at 60°C to constant mass before being immersed in water at room temperature. Samples are removed from the water at 5, 10, 15, 30, 60 minutes and 2, 4, 8 until 24 hours. The fibers were superficially wiped with an absorbent paper in order to eliminate the water adsorbed on their surfaces then weighed. The masses were determined with an accuracy of 0.001g. The water absorption coefficient of fibers is determined by Eqn. (1):

$$W_{abs} = \frac{M_w - M_d}{M_d} \times 100 \qquad (1)$$

W_{abs}: Water absorption (%)
M_w: Wet mass (g)
M_d : Dry mass (g)

Characteristics	Units	Values
Diameter	mm	0.40 - 0.50
Length	mm	1.2
Absolute density	g/cm^3	1.58
Apparent density	g/cm^3	0.28
Water Absorption at 5 min	%	60
Water Absorption at 24 hours	%	110.57
Tensile strength	MPa	94.73
Elongation at crack	mm	9.13
elasticity modulus	GPa	2.05

Table 8: Characteristics of date palm fibers used.

Compositions	Cellulose	Hemicellulose	Lignin	Ash
Proportions (%)	32 – 35.8	24.4 – 28.1	26.7 – 28.7	7

Table 9: Chemical composition of Date Palm fiber mesh [19].

The result on the water absorption kinetics of date palm fibers presented in Fig. 6 is similar to those found by [35,36]. The fibers have two absorption phases: The first has a fairly high slope, which characterizes the initial water absorption, corresponding to the filling of the largest pores. After 5 minutes of total immersion under water, an absorption coefficient of 63.58% was noted. The second absorption phase with a low slope corresponds to the filling of the smallest pores. The water absorption coefficient was 110.67% after 24 hours of preservation of the date palm fibers under water. However, total saturation was not reached, the fibers were kept under water at 48, 72 and 96 hours corresponding to 115.14%, 121.53% and 126.29 % water absorption coefficients respectively. This absorption capacity of date palm fibers is due to their porous structure as shown in Fig. 7.

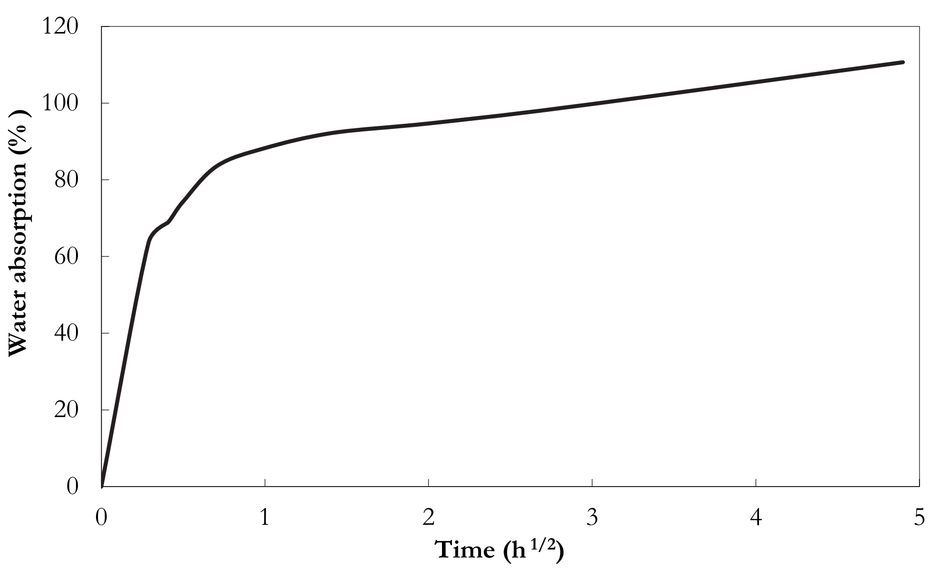
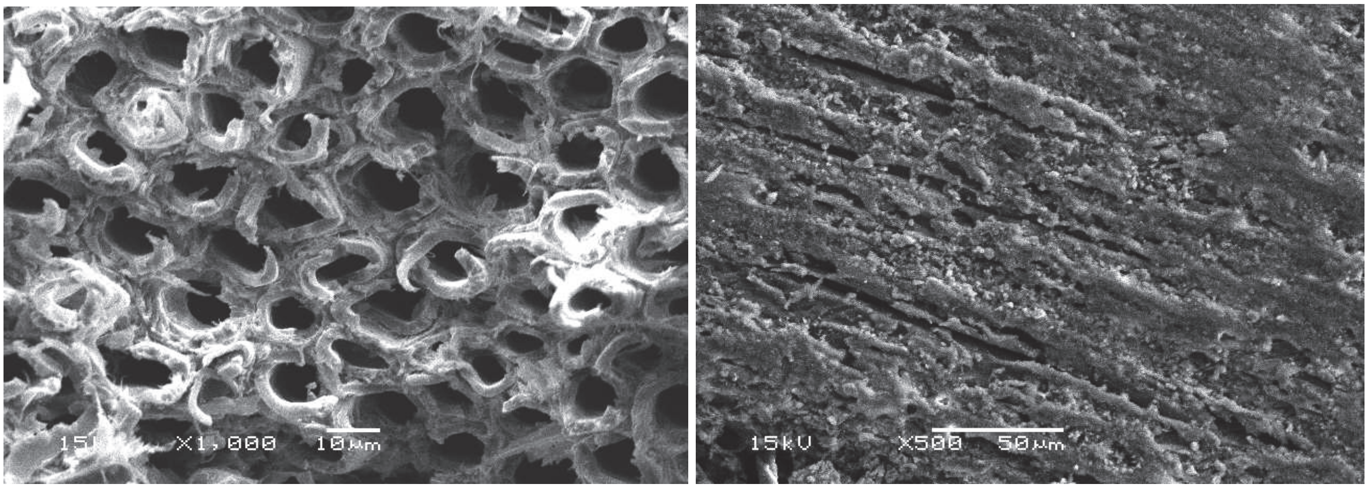


Figure 7: Water absorption kinetics of date palm fibers.

Scanning electron microscope (SEM) observation of the cross section of a date palm fiber (Fig. 8) shows high porosity. Indeed, it consists of a set of tubular shape microfibers with an average diameter of 10 µm (Fig. 8a), which explains its high water absorption capacity. Its exterior surface is characterized by roughness (Fig. 8b) that could improve its grip with the cement matrix.



(a) (b)

Figure 8: Date palm fiber mesh scanning electron microscope observations: (a) cross section and (b) exterior surface.

METHODS

Compositions of SCC

The Japanese method developed by Okamura, H et al [41] was used for the formulation of the various SCC. This study concerns seven SCC: reference non-fiber SCC (RSCC), which served as the basis for the compositions of the six fibered SCC. Three control SCC are reinforced with polypropylene fiber (PPSCC6, PPSCC9 and PPSCC12) and three study SCC fibered with date palm fiber (DPSCC6, DPSCC9, DPSCC12). Three fiber dosages were used 600, 900 and 1200 g/m^3 length of 12 mm. Tab. 10 groups the compositions of the SCC to study.

		Concretes						
Constituents	Unit	RSCC	Polypropylenes fiber			Date palm fiber		
			PPSCC6	SCC PP9	PPSCC12	DPSCC6	DPSCC9	DPSCC12
Cement	(kg/m^3)	350	350	350	350	350	350	350
Limestone filler	(kg/m^3)	200	200	200	200	200	200	200
Water	(kg/m^3)	200	200	200	200	200	200	200
silica sand	(kg/m^3)	384	384	384	384	384	384	384
Quarry sand	(kg/m^3)	284	284	284	284	284	284	284
Gravel (3/8)	(kg/m^3)	490	490	490	490	490	490	490
Gravel (8/16)	(kg/m^3)	460	460	460	460	460	460	460
Plasticizer	(kg/m^3)	6.6	6.6	6.6	6.6	6.6	6.6	6.6
Fibers	(g/m^3)	0	600	900	1200	600	900	1200
W/C	/	0.57	0.57	0.57	0.57	0.57	0.57	0.57
W/F	/	0.36	0.36	0.36	0.36	0.36	0.36	0.36

Table 10: SCC composition.

Mixing sequences:

The constituents are mixed in a concrete mixer with an inclined axis with a capacity of 30 liters. In this work, we followed the same mixing protocol used by several research [36,57–61] as follows: the date palm fibers are pre-wet for 5 minutes in 10% of the volume of total water. This pre-wetting is necessary to reduce water migration from the cement paste to fibers. The aggregates, cement and limestone filler are mixed dry for 60 seconds. Introduction of granular fractions into concrete mixer, in descending order, followed by the addition of fines (cement and addition, the fibers were mixed with a quantity of fines). Keeping the concrete mixer running, added 75% of the total volume of water and mixed for 2 minutes. The adjuvant were diluted in the remaining 25% of water added to the mixture and followed by a final mixing during 2 minutes.

Storage conditions for test specimens

After the manufacture of the test specimens, the molds are covered with a plastic sheet and kept in a humid chamber at room temperature 20°C for 24 hours. Once removed from the mold, the specimens are kept until the moment of the test as follows: the specimens for the mechanical characterization tests were stored in baths filled (saturating humidity) with distilled water (pH= 7, T = 20 ±2 °C, RH = 100%) [62–64] and kept for periods of 2, 7, 14 and 28 days, as well as to control the transfer properties of the SCC and fiber-reinforced SCC. The specimens for the shrinkage tests were kept in a standardized room at a temperature of 20°C and 50% relative humidity [7,61].

Characterization of SCC in the fresh state

The characterization of the SCC in the fresh state was carried out using standard tests. Workability and T500 tests (Fig. 9a) are determined by the Abrams cone-spreading test described in standard NF EN 12350-8 [65]. The mobility of SCC in a confined environment and its ability to cross an area with heavy reinforcement is measured by the L-box test (Fig. 9b) described in standard NF EN 12350-10 [66]. Resistance to segregation is carried out with the sieve stability test (Fig. 9c) described in standard NF EN 12350-11 [67], air content test (Fig. 10a) according to standard NF EN 12350-7 [68] and apparent density measurement (Fig. 10b) according to standard NF EN 12350-6 [69].

(a) (b) (c)

Figure 9: workability study of SCC by the tests: (a) Abrams cone spreading and T500 tests, (b) Filling power tests (the L box) and (c) Segregation stability test.

Characterization of SCC in hardened state

Compressive and in flexural Strength, measurements of cracking time, shrinkage and capillarity water absorption according to the procedure given by reference [40], were realized on SCC in the hardened state.

Strength tests

The compressive strength was evaluated using cubic specimens of dimensions 10×10×10 cm^3 according to standard NF EN 12390-3 [70]. The flexural strength was evaluated using prismatic specimens of dimensions 7.7.28 (cm) according to standard NF EN 12390-5 [71]. The specimens are kept under water at a temperature of 20±2 °C and tested in compressive using a hydraulic press with a capacity of 2000 KN (Fig. 11a) and in flexural using a hydraulic press with a maximum capacity of 150 KN (Fig. 11b), at 2, 7, 14, 28 and 90 days. The result of each test in compressive and in flexural corresponds to the average of three values for each deadline.

(a) (b)

Figure 10: (a) determination of the entrained air with aerometer and (b) measure of concrete density in the fresh state.

(a) (b)

Figure 11: Hydraulics presses: (a) compression test and (b) three points bending test.

Shrinkage test

The experimental protocol for the shrinkage test was carried out in accordance with standard EN P 15-433 [72]. The shrinkage-measuring device is shown in Fig. 12. The specimens used are prisms of dimensions 7×7×28 cm^3 fitted with metal studs at their ends. 24 hours after pouring, the specimens are removed from the mold and kept in a climatic chamber at a temperature of 20 ± 2 (°C) and a relative humidity (H≥50%). The shrinkage measurements are carried out on three specimens for each SCC and at the times of 1, 2, 3, 7, 14, 28, 50 and 90 (days).

Capillary water absorption

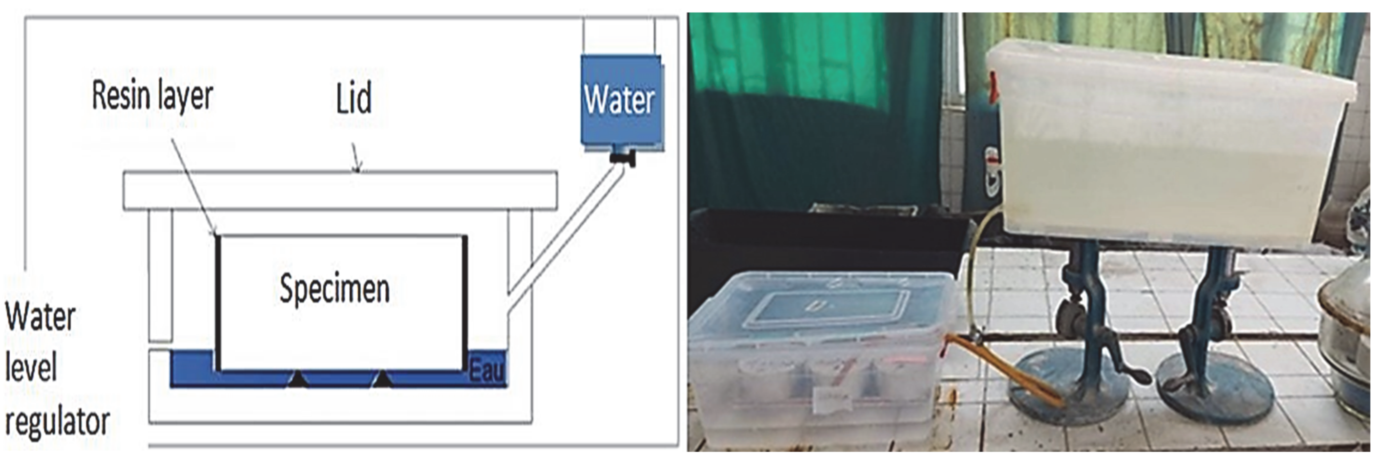
The test was carried out according to the procedure recommended by [73] shown in Fig. 13. The specimens used are cylindrical in shape and have dimensions 11×5 cm^2. After curing for 28 days under water at a temperature of 20 ± 2 °C, the specimens are dried at a temperature of 80°C until constant mass. The side surfaces of the specimens are coated with resin to prevent evaporation of water absorbed during the test, then immersed in the water of the container to a maximum height of 3 mm. At each deadline, the specimens are taken out of the container, wiped with a damp sponge, weighed and then placed back in the container. The capillary absorption coefficient is determined by relation (2) at the following times: 0.25, 0.5, 1, 2, 4, 8 and 24 hours.

$$Ca_t = \frac{M_t - M_0}{A} \text{ (kg/m}^2\text{)} \quad (2)$$

Ca_t: capillary absorption coefficient at (t) time (kg/m²).
M_t: Mass of specimen at (t) time (kg).
M_0: Initial mass of specimen (kg).
A : Specimen section (m²).

(a) (b)

Figure 12: Shrinkage device: (a) retract-meter calibration and (b) shrinkage measurement.



(a) (b)

Figure 13: capillary water absorption measurement: (a) capillary water absorption test [40] and (b) capillary water absorption device.

Results and discussion

Influence of natural and synthetic fibers on the properties of SCC in the fresh state

Workability

The introduction of fibers into the SCC causes a resistance to flow, which translates into a reduction in the self-compacting characteristics, proportionally to the rate of fiber drawing (Fig. 14) in accordance with several researches [74–79].

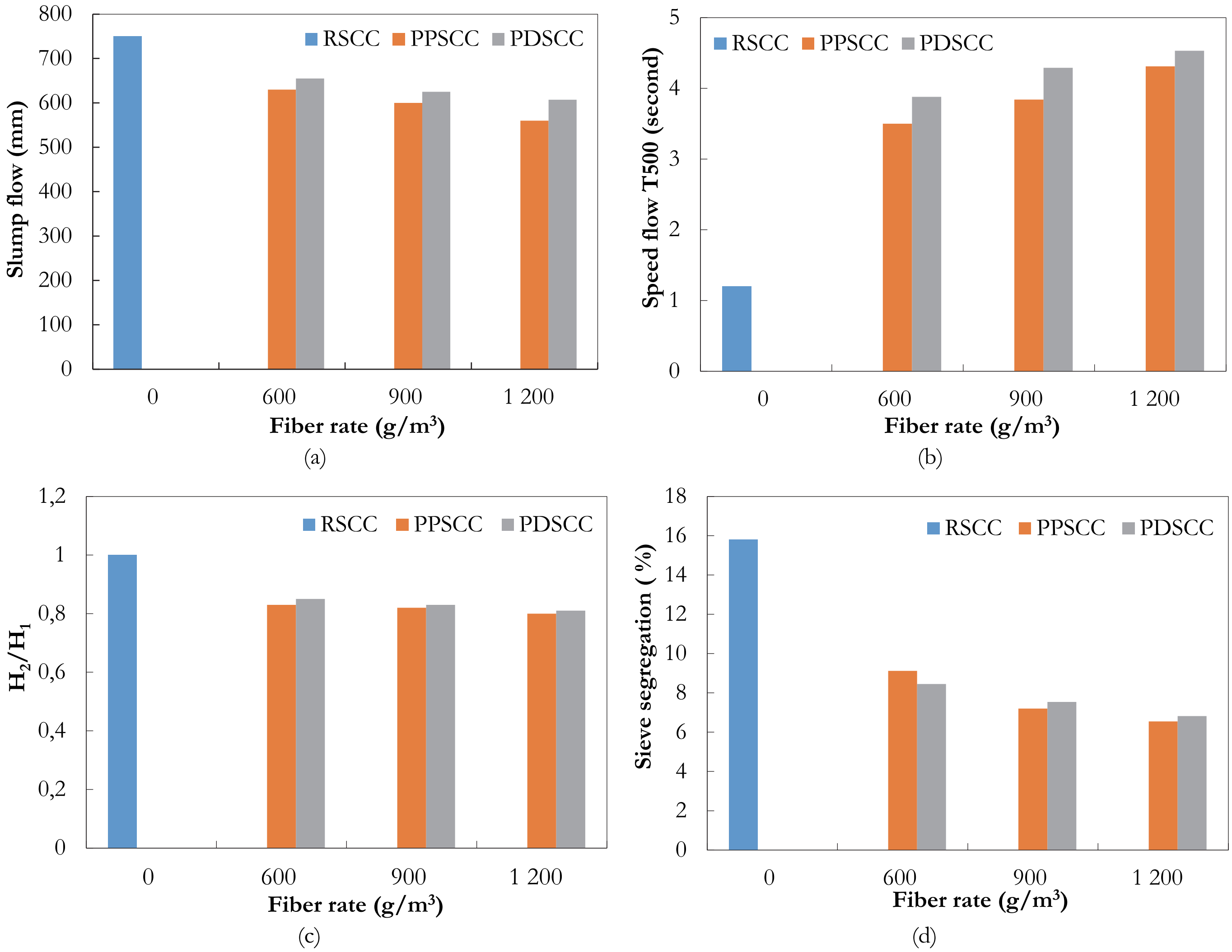


Figure 14: Effect of fiber rate on: (a) Slump flow, (b) speed flow (T500), (c) L-BOX test and (d) segregation resistance.

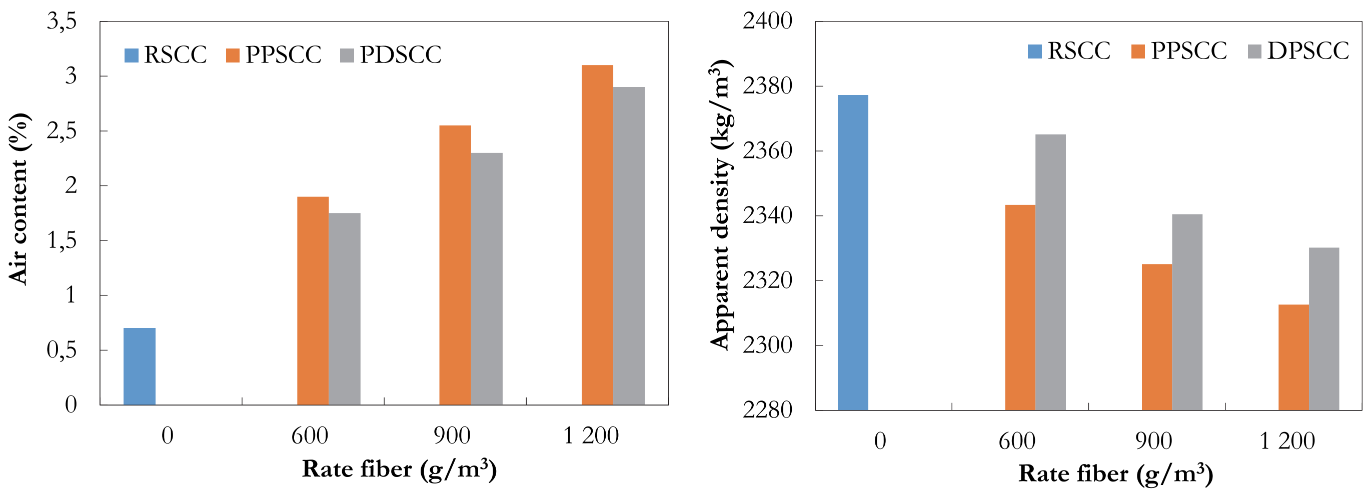
The non-fibered concrete (RSCC) shows no blockage (Fig. 15a). The PPSCC causes a blockage at the level of the steel bars in L-box (Fig. 15b) greater than that caused by the date palm fibers (Fig. 15c). This behavior can be explained by the fact that the number of polypropylene fibers (PPN) is very high equal to 120×10^6 (fibers/kg) [54], compared to that of date palm fibers (DPN), experimentally determined equal to 35×10^4 (fibers/kg).

Air content and apparent density

It is established that the incorporation of fibers in the concrete results in an increase in the entrained air content and a decrease in the apparent density (Fig. 16) with the increase in the fiber dosage. Indeed, the fibers create additional porosity in the concrete at the interface (cement matrix – fiber). The PPSCC and DPSCC have occluded air volumes greater than that of RSCC and apparent densities lower than that of RSCC, in proportion to the fiber dosage, which is in agreement with several researches [36,38,61,80,81]. However, the DPSCC develops a lower volume of occluded air than that of the PPSCC. This behavior can be explained by the fact that for the same fiber dosage, the number of polypropylene fibers is much higher than that of date palm fibers. Thus, with a greater number of fibers, the probability of trapping air bubbles is greater, also increasing the volume of occluded air and therefore decreasing the density of PPSCC compared to DPSCC.

(a) (b) (c)

Figure 15: L-Box test of concretes: (a) RSCC, (b) PPSCC12 and (c) DPSCC12.



(a) (b)

Figure 16: Effect of fiber rate on: (a) air content of SCC and (b) density of SCC.

Influence of natural and synthetic fibers on mechanical behavior of SCC in the hardened state

Influence on compressive and flexural strengths

According to Figs. 17 and 18, it is found that the dosage of 600 g/m³ recommended by the manufacturer of the polypropylene fiber guarantees optimal resistance at any age. It can be noted that the compressive strength of RSCC reached 58 MPA at 90 days. Reinforcement of the SCC by the fibers leads to a noticeable improvement in the resistance to bending compared to the RSCC as demonstrated by different researches. Date palm fibers guarantee the best results compared to polypropylene fibers, this can be explained by the influence of the surface condition of the rough date palm fiber (Fig. 8) which ensures better adhesion with the cementitious matrix [7,36,61] in relation to the surface state of the polypropylene fiber which is smooth.

The compressive strength of the studied concrete is more or less altered; this is related to the increase in the porosity of the concrete (entrained air). It is assumed that it is not the fibers directly that reduce the resistance but rather the occluded air entrained by them. The incorporation of fibers into the concrete leads to a reduction in the compressive strength (Fig. 17).

The fibers modify the porous network of the concrete leading to the formation of pores and more heterogeneity of the structure of the material, in particular at the interface fiber – cementitious matrix that disturbs the compactness of the concrete. This additional porosity obviously leads to a drop in the compressive stress. In addition, a decrease in the densities of the concrete is observed with the increase in the fiber dosage (Fig. 16b). The results found are in agreement with various researches on the use of plant fibers in the cement matrix. [11,35,36,61,74,76,81].
Fiber orientation is an essential parameter to activate the transfer of the load to the fiber [4,5]. In bending, the orientation of the fibers was perpendicular to the load and to the crack propagation [1,34]. Fibers ligate the cracks and prevent their propagation in the cementitious matrix, which increases the bending stress of the fiber material [7,32]. However, in compression, the orientation of the fibers was parallel to the load and to the cracks propagation. In this case, fibers do not have an effective role in terms of their stresses [61,82].

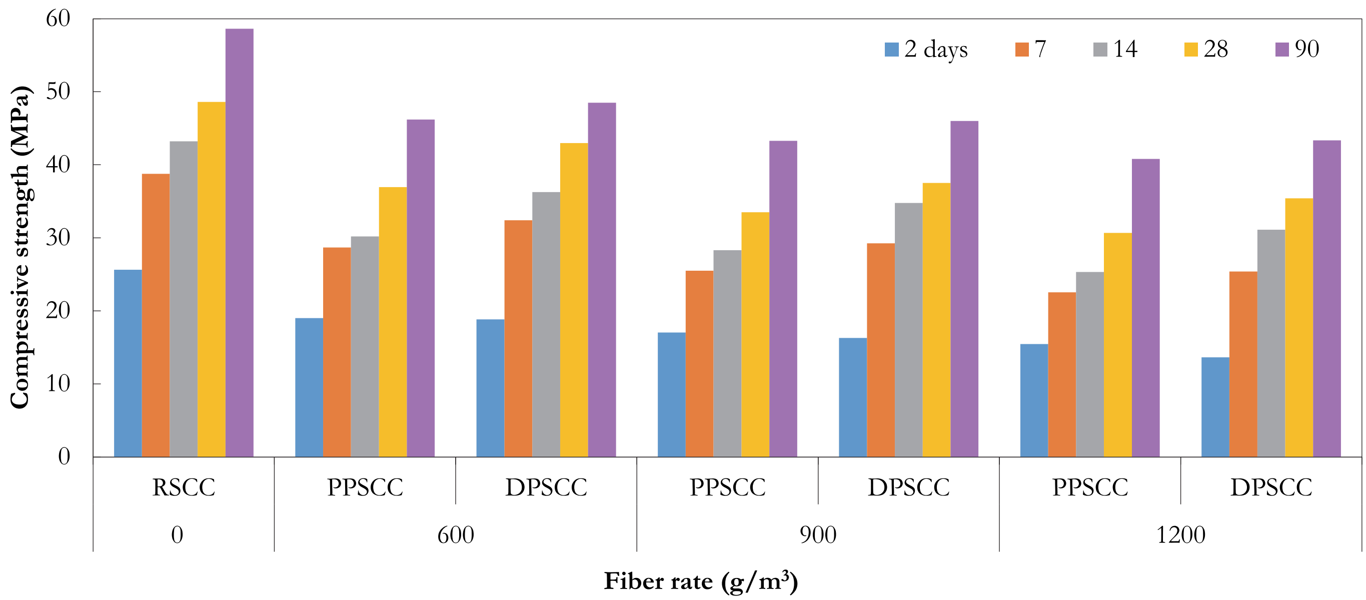


Figure 17: Effect of polypropylene and Date Palm fibers on compressive strength.

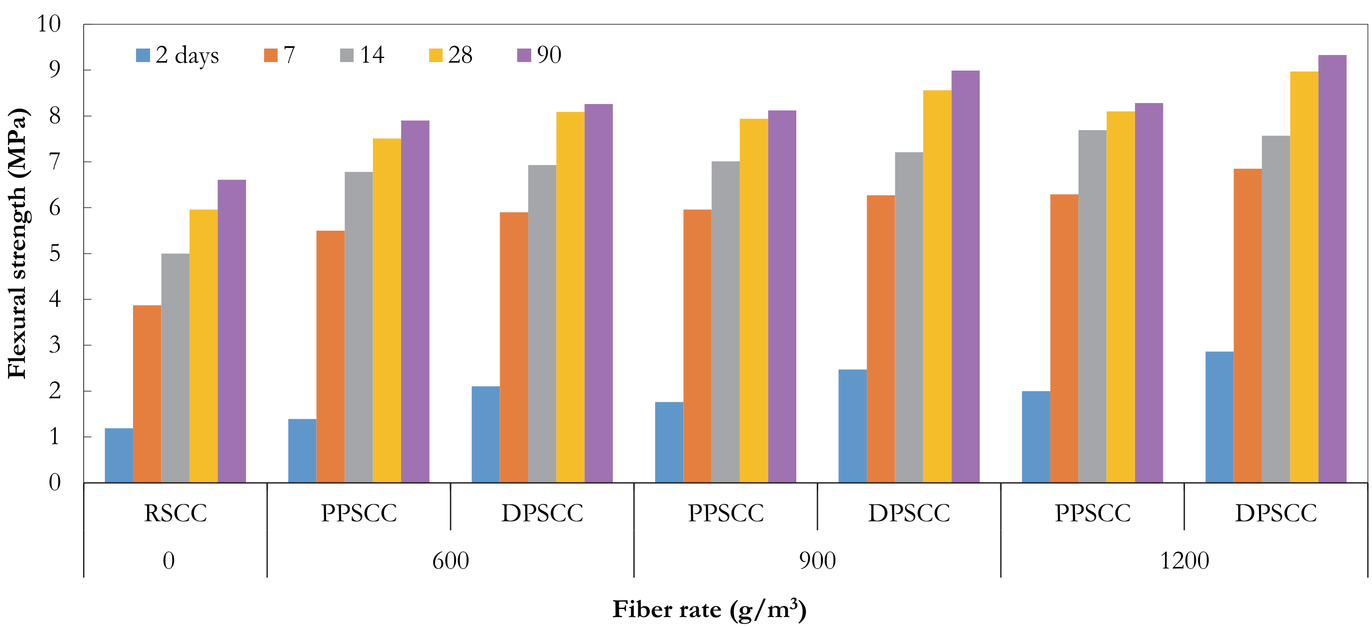


Figure 18: Effect of polypropylene and Date Palm fibers on flexural strength.

Shrinkage

The volume of paste in self-compacting concrete is relatively high, which leads to the appearance of cracks, especially at a young age due to drying shrinkage [83]. The results of the shrinkage measurements (Fig. 19) show that the use of fibers makes it possible to reduce shrinkage. This reduction depends on the dosage and the nature of the fibers. These results are validated by several works [36,83]. Date palm fibers are more effective than polypropylene fibers due to their rough surface.

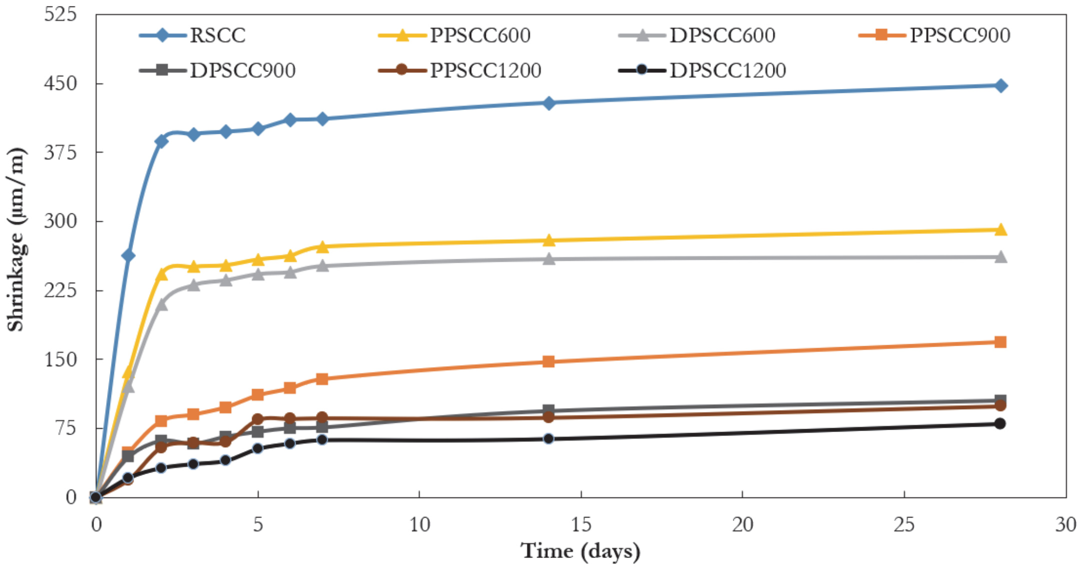


Figure 19: Effect of polypropylene and Date Palm fiber on shrinkage of SCC.

Capillary water absorption

Fig. 20 presents two absorption phases: the first phase is relatively fast, extends up to 8 hours and corresponds to the filling of the largest pores. The second phase is slower and corresponds to the filling of the smallest pores. The introduction of fibers into concrete generates additional porosity at the interface fiber-cement matrix [36,84]. This explains the increase in capillary absorption, which is in agreement with the literature [39,80,85]. Chikhi, M et al [39] emphasizes that the introduction of date palm fibers in a new composite (gypsum-date palm fibers) increases the porosity. The dosage and the nature of the fibers influence the capillary water absorption of the SCC. The DPSCC are characterized by lower coefficients than those of PPSCC. The dosage of 600 g/m^3 seems to be the best dosage.

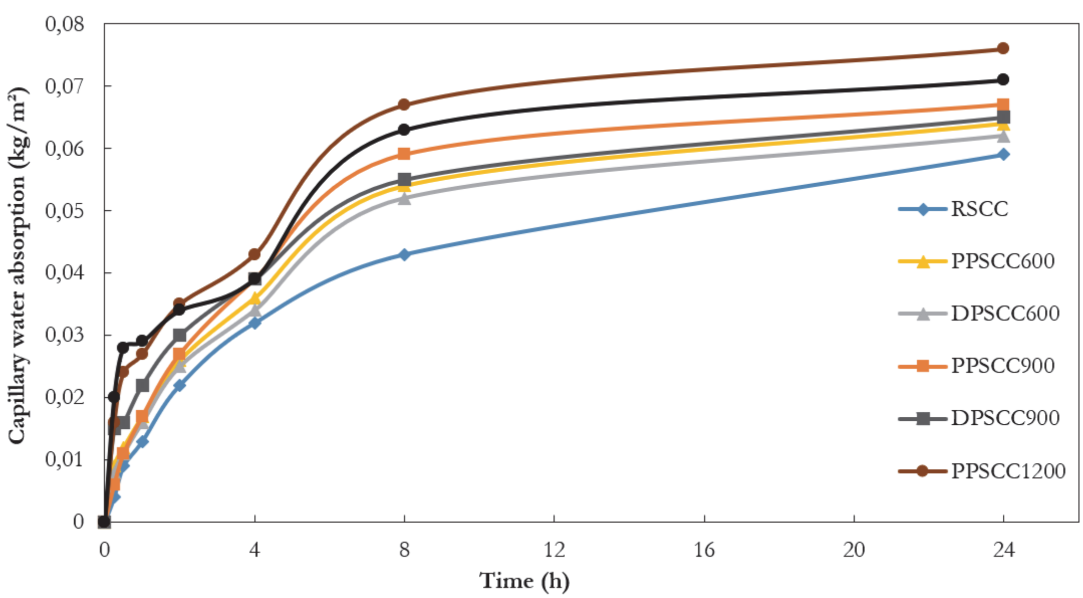


Figure 20: Effect of polypropylene and Date Palm fiber on capillary water absorption.

CONCLUSION

The study of the influence of date palm fibers as reinforcement in self-compacting concretes replacing polypropylene fiber, on the properties in the fresh and hardened states has made it possible to draw the following conclusions:

- Date palm fibers are characterized by a porous and highly hydrophilic microstructure.
- The use of fibers leads to an increase in the content of occluded air in the SCC, which is lower with date palm fibers than with polypropylene fibers.
- The self- compacting parameters of SCC are modified with the introduction of the two types of fibers but remain within the domain of SCC.
- The apparent density of concrete decreases more with polypropylene fibers than with date palm fibers.
- The introduction of fibers into the SCC leads to a decrease in compressive strength. The bending strength is significantly improved; hence, the date palm fiber guarantees the best results both in compression and in flexion.
- Polypropylene fibers significantly reduce shrinkage and the best result is obtained with date palm fibers.
- The results obtained are encouraging. Date palm fibers could replace polypropylene fibers in the development of fiber SCC, due to the environmental, technical and economic advantages.

ACKNOWLEDGMENTS

The authors thankfully acknowledge Materials, Geomaterials and Environment Laboratory (LMGE-Annaba) of Badji Mokhtar Annaba University (Algeria) providing of equipment required for behavioral testing.

NOMENCLATURE

SCC: self-compacting concrete.
RSCC: reference self-compacting concrete (without fibers).
PPSCC: polypropylene self-compacting concrete.
DPSCC: date palm self-compacting concrete.
PPSCC6: self-compacting concrete with 600 grams of polypropylene fibers.
PPSCC9: self-compacting concrete with 900 grams of polypropylene fibers.
PPSCC12: self-compacting concrete with 1200 grams of polypropylene fibers.
DPSCC6: self-compacting concrete with 600 grams of date palm fibers.
DPSCC9: self-compacting concrete with 900 grams of date palm fibers.
DPSCC12: self-compacting concrete with 1200 grams of date palm fibers.
W/C: report water on cement.
W/F: Report water on fine (Cement+ Limestone fillers).
NDP: number of date palm fibers.
NPP: number of polypropylene fibers.

REFERENCE

[1] Sellami, A., Merzoud, M., Amziane, S. (2013). Improvement of mechanical properties of green concrete by treatment of the vegetals fibers, Constr. Build. Mater., 47, pp. 1117–1124, DOI: 10.1016/j.conbuildmat.2013.05.073.
[2] Menadi, S., Benazzouk, A., Douzane, O., Merzoud, M., Habita, M.F., Langlet, T. (2013). Etude de la faisabilite d'un composite a matrice cimentaire renforce de fibres de jute, Synthèse Rev. Des Sci. La Technol., 27, pp. 40–49.
[3] Ramesh, M., Palanikumar, K., Reddy, K.H. (2017). Plant fibre based bio-composites: Sustainable and renewable green materials, Renew. Sustain. Energy Rev., 79, pp. 558–584.

[4] Benzerara, M., Guihéneuf, S., Belouettar, R., Perrot, A. (2021). Combined and synergic effect of algerian natural fibres and biopolymers on the reinforcement of extruded raw earth, Constr. Build. Mater., 289, pp. 123211, DOI: 10.1016/j.conbuildmat.2021.123211.
[5] Zaid, I., Merzoud, M., Benazzouk, A. (2021). Morphological and mineralogical analysis of treated Diss fibers and their effect on physico-mechanical characteristics of Diss concrete based on alternative binder, Constr. Build. Mater., 307, pp. 124936, DOI:10.1016/j.conbuildmat.2021.124936.
[6] Sellami, A., Bouayad, D., Benazzouk, A., Amziane, S., Merzoud, M. (2022). Study of toughness and thermal properties of bio-composite reinforced with diss fibers for use as an insulating material, Energy Build., 276, pp. 112527, DOI: 10.1016/j.enbuild.2022.112527.
[7] Boutarfa, M., Belouettar, R., Makradi, A. (2018). Comparative Study of Cement Mortar Reinforced with Vegetable Fibers Alfa, Date Palm and Diss: Mechanical Properties and Shrinkage, J. Mater. Environ. Sci., 9, pp. 2304–14.
[8] Biskri, Y., Benzerara, M., Babouri, L., Dehas, O., Belouettar, R. (2022). Valorization and recycling of packaging belts and post-consumer PET bottles in the manufacture of sand concrete, Frat. Ed Integrità Strutt., 16(62), pp. 225–239, DOI: 10.3221/IGF-ESIS.62.16.
[9] Lilargem Rocha, D., Tambara Júnior, L.U.D., Marvila, M.T., Pereira, E.C., Souza, D., de Azevedo, A.R.G. (2022). A Review of the Use of Natural Fibers in Cement Composites: Concepts, Applications and Brazilian History, Polymers (Basel)., 14(10), pp. 2043.
[10] Achour, A., Ghomari, F., Belayachi, N. (2017). Properties of cementitious mortars reinforced with natural fibers, J. Adhes. Sci. Technol., 31(17), pp. 1938–1962.
[11] Fokam, C.B., Toumi, E., Kenmeugne, B., Meva'a, L., Mansouri, K. (2020). Cement Mortar Reinforced with Palm Nuts Naturals Fibers: Study of the Mechanical Properties., Rev. Des Compos. Des Matériaux Avancés, 30(1).
[12] Baley, C. (2005). Fibres naturelles de renfort pour matériaux composites, Ed. Techniques Ingénieur.
[13] Brandt, A.M. (2008). Fibre reinforced cement-based (FRC) composites after over 40 years of development in building and civil engineering, Compos. Struct., 86(1–3), pp. 3–9.
[14] Aziz, M.A., Paramasivam, P., Lee, S.L. (1981). Prospects for natural fibre reinforced concretes in construction, Int. J. Cem. Compos. Light. Concr., 3(2), pp. 123–132.
[15] Tonoli, G.H.D., Savastano Jr, H., Fuente, E., Negro, C., Blanco, A., Lahr, F.A.R. (2010). Eucalyptus pulp fibres as alternative reinforcement to engineered cement-based composites, Ind. Crops Prod., 31(2), pp. 225–232.
[16] Li, Y., Mai, Y.-W., Ye, L. (2000). Sisal fibre and its composites: a review of recent developments, Compos. Sci. Technol., 60(11), pp. 2037–2055.
[17] Sudin, R., Swamy, N. (2006). Bamboo and wood fibre cement composites for sustainable infrastructure regeneration, J. Mater. Sci., 41(21), pp. 6917–6924.
[18] Agopyan, V., Savastano Jr, H., John, V.M., Cincotto, M.A. (2005). Developments on vegetable fibre--cement based materials in São Paulo, Brazil: an overview, Cem. Concr. Compos., 27(5), pp. 527–536.
[19] Brundtland, G.H., Khalid, M., others. (1988). Notre avenir à tous, Editions du Fleuve, Montréal, QC, CA.
[20] Dittenber, D.B., GangaRao, H.V.S. (2012). Critical review of recent publications on use of natural composites in infrastructure, Compos. Part A Appl. Sci. Manuf., 43(8), pp. 1419–1429.
[21] Joshi, S. V., Drzal, L.T., Mohanty, A.K., Arora, S. (2004). Are natural fiber composites environmentally superior to glass fiber reinforced composites?, Compos. Part A Appl. Sci. Manuf., 35(3), pp. 371–376.
[22] Ghavami, K., Toledo Filho, R.D., Barbosa, N.P. (1999). Behaviour of composite soil reinforced with natural fibres, Cem. Concr. Compos., 21(1), pp. 39–48.
[23] Savastano Jr, H., Agopyan, V., Nolasco, A.M., Pimentel, L. (1999). Plant fibre reinforced cement components for roofing, Constr. Build. Mater., 13(8), pp. 433–438.
[24] Ghosn, S., Cherkawi, N., Hamad, B. (2020). Studies on Hemp and Recycled Aggregate Concrete, Int. J. Concr. Struct. Mater., 14(1), pp. 1–17.
[25] Daniel, J.I., Ahmad, S.H., Arockiasamy, M., Ball, H.P., Batson, G.B., Criswell, M.E., Dorfmueller, D.P., Fernandez, A. V., Gale, D.M., Antonio, J., others. (2002). State-of-the-art report on fiber reinforced concrete reported by ACI Committee 544, ACI J, 96, pp. 1–66.
[26] Alene, T.E., Mohammed, T.A., Gualu, A.G. (2022). Use of Sisal Fiber and Cement to Improve Load Bearing Capacity of Mud Blocks, Mater. Today Commun., , pp. 104557, DOI: 10.1016/j.mtcomm.2022.104557.
[27] Ren, G., Wang, J., Wen, X., Gao, X. (2022). Using sol-gel deposition of nanosilica to enhance interface bonding between sisal fiber and ultra-high performance concrete, Cem. Concr. Compos., 133, pp. 104705, DOI: 10.1016/j.cemconcomp.2022.104705.
[28] Cláudia dos Santos, A., Gatti Cardoso, F., José da Silva, R., de Fátima Gorgulho, H., Hallak Panzera, T. (2022).

Modification of short sugarcane bagasse fibres for application in cementitious composites: A statistical approach to mechanical and physical properties, Constr. Build. Mater., 353, pp. 129072, DOI: 10.1016/j.conbuildmat.2022.129072.
[29] Riofrio, A., Cornejo, M., Baykara, H. (2022). Environmental performance of bamboo fibers and sugarcane bagasse reinforced metakaolin-based geopolymers, Case Stud. Constr. Mater., 17, pp. e01150, DOI: 10.1016/j.cscm.2022.e01150.
[30] Madhwani, H., Sathyan, D., Mini, K.M. (2021). Study on durability and hardened state properties of sugarcane bagasse fiber reinforced foam concrete, Mater. Today Proc., 46, pp. 4782–478 7, DOI: 10.1016/j.matpr.2020.10.313.
[31] Mehrzad, S., Taban, E., Soltani, P., Samaei, S.E., Khavanin, A. (2022). Sugarcane bagasse waste fibers as novel thermal insulation and sound-absorbing materials for application in sustainable buildings, Build. Environ., 211, pp. 108753, DOI: 10.1016/j.buildenv.2022.108753.
[32] Messas, T., Achoura, D., Abdelaziz, B., Mamen, B. (2022). Experimental investigation on the mechanical behavior of concrete reinforced with Alfa plant fibers, Frat. Ed Integrità Strutt., 16(60), pp. 102–113, DOI: 10.3221/IGF-ESIS.60.08.
[33] Mihoub, I., Khelifa, M.R., Mezhoud, S. (2020). Impact of Elevated Temperature on the Properties of Concretes Reinforced with Alfa Fiber, Civ. Environ. Eng. Reports, 30(3), pp. 161–185, DOI: 10.2478/ceer-2020-0038.
[34] Ziane, S., Khelifa, M.-R., Mezhoud, S., Beroual, A., Medaoud, S. (2021). Experimental Study on the Durability Characteristics of Several Vegetable Fiber Reinforced Concretes Exposed to Sodium Sulfate, Civ. Environ. Eng. Reports, 31(1), pp. 1–28, DOI: 10.2478/ceer-2021-0001.
[35] Kriker, A., Debicki, G., Bali, A., Khenfer, M.M., Chabannet, M. (2005). Mechanical properties of date palm fibres and concrete reinforced with date palm fibres in hot-dry climate, Cem. Concr. Compos., 27(5), pp. 554–564.
[36] Tioua, T., Kriker, A., Barluenga, G., Palomar, I. (2017). Influence of date palm fiber and shrinkage reducing admixture on self-compacting concrete performance at early age in hot-dry environment, Constr. Build. Mater., 154, pp. 721–733, DOI: 10.1016/j.conbuildmat.2017.07.229.
[37] Tahri, K., Fadlaoui, S., Bedjaoui, H., Khechai, S., Mehaoua, M.S., Bennaceur, M., Rey, H. (2019).Contribution à l'étude du développement et de la biomasse racinaire du palmier dattier (Phoenix dactylifera L.) dans l'Oasis de Biskra. 1st National Seminar on Biodiversity and Valorization of Organic Products in Arid and Semi-Arid Regions, University of El-Oued, Algeria, p. 17.
[38] Ali-Boucetta, T., Ayat, A., Laifa, W., Behim, M. (2021). Treatment of date palm fibres mesh: Influence on the rheological and mechanical properties of fibre-cement composites, Constr. Build. Mater., 273, pp. 121056, DOI: 10.1016/j.conbuildmat.2020.121056.
[39] Chikhi, M. (2016). Young's modulus and thermophysical performances of bio-sourced materials based on date palm fibers, Energy Build., 129, pp. 589–597, DOI: 10.1016/j.enbuild.2016.08.034.
[40] Jonoobi, M., Shafie, M., Shirmohammadli, Y., Ashori, A., Hosseinabadi, H.Z., Mekonnen, T. (2019). A review on date palm tree: Properties, characterization and its potential applications, J. Renew. Mater., 7(11), pp. 1055–1075.
[41] Okamura, H., Ozawa, K. (1996). Self-compacting high performance concrete, Struct. Eng. Int., 6(4), pp. 269–270, DOI: 10.2749/101686696780496292.
[42] AFGC. (2008). Les BAP : recommandations provisoires pour l'emploi des Bétons autoplaçants, .
[43] Le Roy, R. (1995). Déformations instantanées et différées des bétons à hautes performances--Etude paramétrique en fonction de la formulation--Proposition de modèles simplifiés, Ec. Natl. Des Ponts Chaussées.
[44] NA 442. (2005). Ciment, composition, spécifications et critères de conformité des ciments courants, Norme Algérienne.
[45] NF P15-435. (2021). Méthodes d'essais des ciments - Détermination de la masse volumique, Eur. Stand. AFNOR.
[46] NF EN 196-3. (2017). Méthodes d'essai des ciments - Partie 3 : détermination du temps de prise et de la stabilité.
[47] NF EN 1097-3. (1998). Essais pour déterminer les caractéristiques mécaniques et physiques des granulats - Partie 3 : méthode pour la détermination de la masse volumique en vrac et de la porosité intergranulaire, Eur. Stand. AFNOR.
[48] XP P18-540. (1997). Granulats - Définitions, conformité, spécifications, Eur. Stand. AFNOR.
[49] NF EN 933-8. (2012). Essais pour déterminer les caractéristiques géométriques des granulats - Partie 8 : évaluation des fines - Équivalent de sable, Eur. Stand. AFNOR.
[50] P18-573. (1990). Granulats - Essai de Los Angeles, Eur. Stand. AFNOR.
[51] NF EN 1097-1. (2011). Essais pour déterminer les caractéristiques mécaniques et physiques des granulats - Partie 1 : détermination de la résistance à l'usure (micro-Deval), Eur. Stand. AFNOR.
[52] NF P 18-560. (1990). Granulats - Analyse granulométrique par tamisage, Eur. Stand. AFNOR.
[53] ViscoCrete 3045. (2021). Product leaflet Sika plasticizer ViscoCrete 3045, Sika Plast. Data Sheet, pp. 2.
[54] Sika fiber 12-34. (2020). Product leaflet Sika polypropylene Fiber 12-34, Polypropyl. Fiber Data Sheet, pp. 3.
[55] Bekkouche, S.R., Benzerara, M., Zada, U., Muhammad, G., Ali, Z. (2022). Use of Eco-Friendly Materials in the

Stabilization of Expansive Soils, Buildings, 12(10), pp. 1770, DOI: 10.3390/buildings12101770.
[56] Magniont, C. (2010).Contribution à la formulation et à la caractérisation d'un éco-matériau de construction à base d'agro-ressources. Doctoral thesis. INSA Toulouse, France.
[57] de Bruijn, P.B., Jeppsson, K.-H., Sandin, K., Nilsson, C. (2009). Mechanical properties of lime--hemp concrete containing shives and fibres, Biosyst. Eng., 103(4), pp. 474–479, DOI: 10.1016/j.biosystemseng.2009.02.005.
[58] Cerezo, V. (2005). Propriétés mécaniques, thermiques et acoustiques d'un matériau à base de particules végétales: approche expérimentale et modélisation théorique. Doctoral thesis. INSA Lyon, France.
[59] Monreal, P., Mboumba-Mamboundou, L.B., Dheilly, R.M., Quéneudec, M. (2011). Effects of aggregate coating on the hygral properties of lignocellulosic composites, Cem. Concr. Compos., 33(2), pp. 301–308, DOI: 10.1016/j.cemconcomp.2010.10.017.
[60] Nozahic, V. (2012).Vers une nouvelle démarche de conception des bétons de végétaux ligno-cellulosiques basée sur la compréhension et l'amélioration de l'interface liant/végétal : application à des granulats de chènevotte et de tige de tournesol associés à un liant ponce/cha. Doctoral thesis. Blaise Pascal University, France.
[61] Laifa, W., Behim, M., Turatsinze, A., Ali-Boucetta, T. (2014). Caractérisation d'un béton autoplaçant avec addition de laitier cristallisé et renforcé par des fibres de polypropylène et de diss, Synthèse Rev. Des Sci. La Technol., 29, pp. 100–10.
[62] Rahim, O., Achoura, D., Benzerara, M., Bascoulès-Perlot, C. (2021). Experimental contribution to the study of the physic-mechanical behavior and durability of high-performance concretes based on ternary binder (cement, silica fume and granulated blast furnace slag), Frat. Ed Integrità Strutt., 16(59), pp. 344–358, DOI: 10.3221/IGF-ESIS.59.23.
[63] Melais, S., Bouali, M.F., Melaikia, A., Amirat, A. (2021). Effects of coarse sand dosage on the physic-mechanical behavior of sand concrete, 56, pp. 151–159, DOI: 10.3221/IGF-ESIS.56.12.
[64] Kebaili, B., Benzerara, M., Menadi, S., Kouider, N., Belouettar, R. (2022). Effect of parent concrete strength on recycled concrete performance, Frat. Ed Integrità Strutt., 16(62), pp. 14–25, DOI: 10.3221/IGF-ESIS.62.02.
[65] NF EN 12350-08. (2010). Essai pour béton frais - Partie 8 : béton autoplaçant - Essai d'étalement au cône d'Abrams, Eur. Stand. AFNOR.
[66] NF EN 12350-10. (2010). Essai pour béton frais - Partie 10 : béton autoplaçant - Essai à la boîte en L, Eur. Stand. AFNOR.
[67] NF EN 12350-11. (2010). Essai pour béton frais - Partie 11 : béton autoplaçant - Essai de stabilité au tamis, Eur. Stand. AFNOR.
[68] NF EN 12350-7. (2019). Essais pour béton frais - Partie 7 : teneur en air - Méthode de la compressibilité, Eur. Stand. AFNOR.
[69] NF EN 12350-6. (2012). Essai pour béton frais - Partie 6 : masse volumique, Eur. Stand. AFNOR.
[70] NF EN 12390-3. (2019). Essai pour béton durci Partie 3: Résistance à la compression des éprouvettes, Eur. Stand. AFNOR.
[71] NF EN 12390-5. (2019). Essai pour béton durci, partie5 : résistance à la flexion sur éprouvette, Eur. Stand. AFNOR.
[72] NF P 15-433. (1994). Méthodes d'essais des ciments - Détermination du retrait et du gonflement, Eur. Stand. AFNOR.
[73] Arliguie, G., Hugues, H. (2007). GranDuBé, Grandeurs Associées à la Durabilité des Bétons.
[74] El-Dieb, A.S., Taha, M.M.R. (2012). Flow characteristics and acceptance criteria of fiber-reinforced self-compacted concrete (FR-SCC), Constr. Build. Mater., 27(1), pp. 585–596, DOI: 10.1016/j.conbuildmat.2011.07.004.
[75] Ding, Y., Liu, S., Zhang, Y., Thomas, A. (2008). The investigation on the workability of fibre cocktail reinforced self-compacting high performance concrete, Constr. Build. Mater., 22(7), pp. 1462–1470, DOI: 10.1016/j.conbuildmat.2007.03.034.
[76] Khayat, K.H., Roussel, Y. (2000). Testing and performance of fiber-reinforced, self-consolidating concrete, Mater. Struct., 33(6), pp. 391–397.
[77] Grünewald, S., Walraven, J.C. (2001). Parameter-study on the influence of steel fibers and coarse aggregate content on the fresh properties of self-compacting concrete, Cem. Concr. Res., 31(12), pp. 1793–1798, DOI: 10.1016/S0008-8846(01)00555-5.
[78] Dhonde, H.B., Mo, Y.L., Hsu, T.T.C., Vogel, J. (2007). Fresh and hardened properties of self-consolidating fiber-reinforced concrete, ACI Mater. J., 104(5), pp. 491.
[79] Grzesiak, S., Pahn, M., Schultz-Cornelius, M., Harenberg, S., Hahn, C. (2021). Influence of Fiber Addition on the Properties of High-Performance Concrete, Materials (Basel)., 14(13), pp. 3736, DOI: 10.3390/ma14133736.
[80] Yadegaran, I., Mahoutian, M., Shekarchi, M., Libre, N.A. (2007).106. Effect of polypropylene fibers on shrinkage of self-compacting concrete. 5th International RILEM Symposium on Self-Compacting Concrete, pp. 707–713.
[81] Tahar, A.-B., Tahar, T., Mourad, B., Abdelouahed, K., Cherif, B., Walid, L. (2016). Effet de l'incorporation des fibres

d'Alfa sur le comportement des bétons autoplaçants, J. Mater. Process. Environ., 4(1), pp. 5–10.
[82] Laborel-Préneron, A., Aubert, J.-E., Magniont, C., Tribout, C., Bertron, A. (2016). Plant aggregates and fibers in earth construction materials: A review, Constr. Build. Mater., 111, pp. 719–734.
[83] Leong, G.W., Mo, K.H., Loh, Z.P., Ibrahim, Z. (2020). Mechanical properties and drying shrinkage of lightweight cementitious composite incorporating perlite microspheres and polypropylene fibers, Constr. Build. Mater., 246, pp. 118410.
[84] Haba, B., Agoudjil, B., Boudenne, A., Benzarti, K. (2017). Hygric properties and thermal conductivity of a new insulation material for building based on date palm concrete, Constr. Build. Mater., 154, pp. 963–971.
[85] El Hilali, A. (2009). Étude expérimentale de la rhéologie et du comportement des bétons autoplaçants (BAP): Influence des fines calcaires et des fibres végétales. Doctoral thesis. Cergy Pontoise University, France.