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WORKABILITY AND DURABILITY OF SAND CONCRETE BASED ON CEMENTITIOUS MATRIX AND PLASTIC ADDITIVES

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ABSTRACT

The "concrete" material, which is a mixture of several components such as water, cement and aggregates, has remained since the beginning of the 19th century the most important element in civil engineering works. In fact, good concrete is the one that satisfies these qualities: mechanical strength, unalterability, impermeability and finally ease of mixing, transport and installation without segregation.

However, we are faced with the need to find a combination of constituents to obtain a concrete that is fluid at the same time to ensure ease of pouring and optimize the flow time, both durable and therefore of a high mechanical resistance that can happen to resist the stresses associated with aggressive media.

In this research project, at the first time we will act on the fluidity to optimize the flow time and on the resistance to enhance the compressive and flexural strength of cementitious material. Finally, for more precise and general results, we decided to use three types of sand.

According to the results found we can conclude that limestone fillers are the most efficient addition which contribute to enhance the fluidity of cementitious concrete and optimize its flow time, but they are so expensive for large quantities, the substitution of sand for plastic grains leads to remarkable decrease in the flow time of all materials *mixes and a great reduction in their densities, as well as improving the performance of sand concretes. In addition, the strengthening of the cementitious matrix with polypropylene fibers shows a marked improvement in their compressive strength.*

Keywords: Fluidity, Fiber, Compressive Strength, Sand Concrete, Plastic Grains.

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1. INTRODUCTION

Endowed with more than 3500 km of coastline and a Sahara of more than 266000 km2, Morocco is considered among the countries rich in sand. Therefore, in the present research work we have opted to develop the use of sand which is an abandoned local resource in Morocco in the design of sand-based concretes [1, 2], it is a new range of building materials composed mainly of water, cement and sand unlike traditional concrete which also contains gravel. Some researchers have considered the introduction of some additions such as super plasticizers, metallic fibers and glass powder [3, 4, 5, and 6], etc.….

Among the essential criteria to be taken into account in the formulation of concretes: fluidity [7,8,9]and mechanical strength[3,10,11,12], indeed these two characteristics play a fundamental role in the classification of concretes, Several research works have been carried out in order to reduce the disadvantages of cementitious materials and to improve their physical and mechanical performance such as fluidity[7,8,9]and strength to compression[3,10,11,12] , for this purpose over the years modifications have been made to the cementitious matrices either by acting on the granular structure or by incorporating some elements like (adjuvant, fiber) . Etc.

To facilitate the mixing, transport and placement of concrete without segregation it is essential to improve its fluidity. To achieve this objective, we added silica fume, limestone fillers and plastic grains used in soles to the control sample and compared the evolution of the flow time according to the two additives.

Second, to reduce the risk of cracking, shrinkage and creep, we plan to increase compressive and bending strength in the long term, so to realize this objective we have replaced proportions of cement with polypropylene fibers and part of the sand with grains obtained from the grinding of plastic used in the soles.

In this study we opted to use 3 types of sand, the first is sand extracted from the river of Sebou, the second is sea sand and the third one is the standard sand used by the factory Lafarge Holcim. We have chosen to diversify the types of sands to have a targeted idea of the influence of the nature of this main component on the results obtained.

2. MATERIAL USED

2.1. Cement

The cement used is the CPJ 55 seawater intake manufactured in Morocco and more precisely within the Lafarge-Holcim plant in Meknes, a specific surface Blaine of 359,6 m2/kg, an absolute density of 3080 kg/m3 and an average compressive strength at 28 days of 48,47MPa is used for all mixtures of sand concrete.

Table 1 constituents of the cement used in the research study

Constituants (%)						
With gypse				Without gypse		
Clinker	Calcaireous	Pzz	Gypsum	Clinker	Calcaireous	Pouzz
75,6	20,9		3,5	78,34	21,66	0

Table 2 chemical composition of the cement used

Chemical Composition																
% RI	P F	% SiO2 t	% Al2O3	% Fe2O3	%CaO	% MgO	% P2O5	% TiO2	Mn2O3	Cr2O3	% SO3	% CL	% K2O	% Na2O	Total	Alc. Eqvl
4,12	8,86	18,34	4,5	2,62	60,07	1,21	0,04	0,24	0,03		2,61	0,014	0,46	0,08	99,07	0,38

2.2. Sand

Sand is a fundamental constituent of concrete, in this study we have chosen to use three types of sand to determine the influence of the nature of sand on the physic-mechanical performances and to verify the validity of the additions used for different types of sand.

2.2.1. The river of Sebou Sand

At first, we used the sand extracted from the river of Sebou, below the characteristic table and the granulometric curve of the sand used.

Table 3 The characteristic table of the river of Sebou Sand

Characteristics	Wadi Sebou sand
Module of finess Mf	2,71
Bulk density (g/cm3)	1,4
Absolute density (g/cm3)	2,5
Clineliness (%)	80
Water absorption (%)	1,31

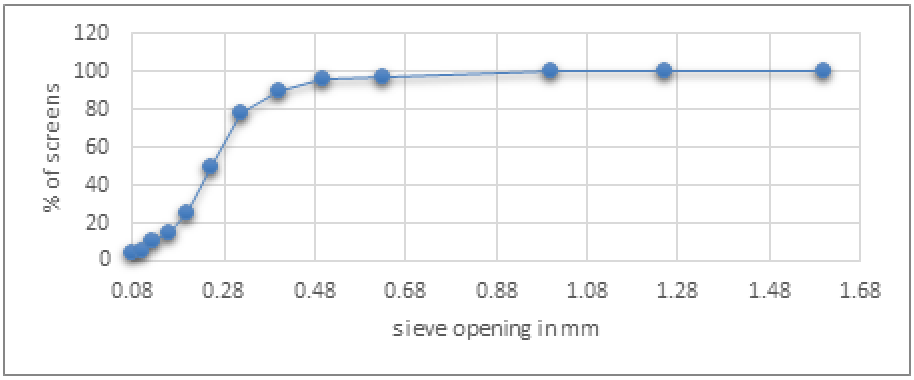

Figure 1 The grain size curve of the river of Sebou sand

2.2.2. Sea Sand

Secondly, we used the sand extracted from sea, more precisely from Casablanca beach, below the characteristic table and the granulometric curve of the sand used.

Table 4 the characteristic table of Sea Sand

Characteristics	Sea sand
Module of finess Mf	1,25
Bulk density (g/cm3)	1,395
Absolute density (g/cm3)	2,61
Clineliness (%)	87
Water absorption (%)	0,9

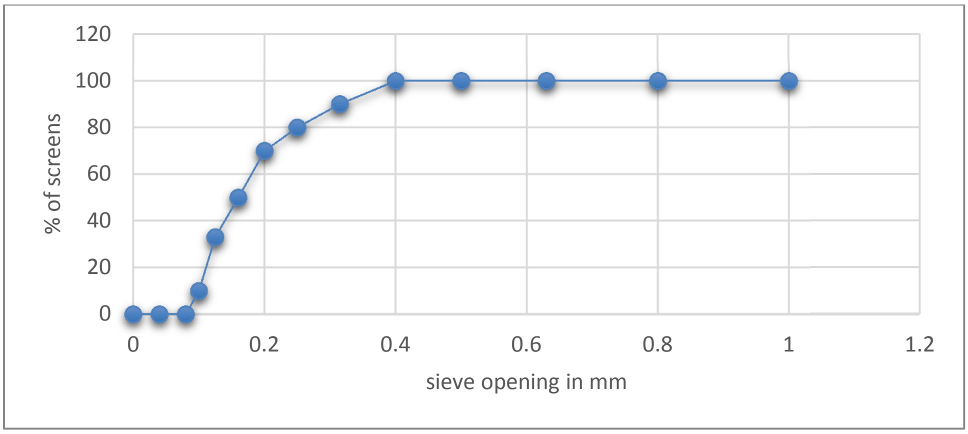

Figure 2 The grain size curve of the sea sand

2.2.3. Standard sand

Thirdly, we used the standard sand used by Lafarge-Holcim factory, below the characteristic table and the granulometric curve of the sand used.

Table 5 The characteristic table of Standard Sand

Characteristics	standard sand
Module of finess Mf	2,65
Bulk density (g/cm3)	1,4
Absolute density (g/cm3)	2,64
Clineliness (%)	87
Water absorption (%)	0,2

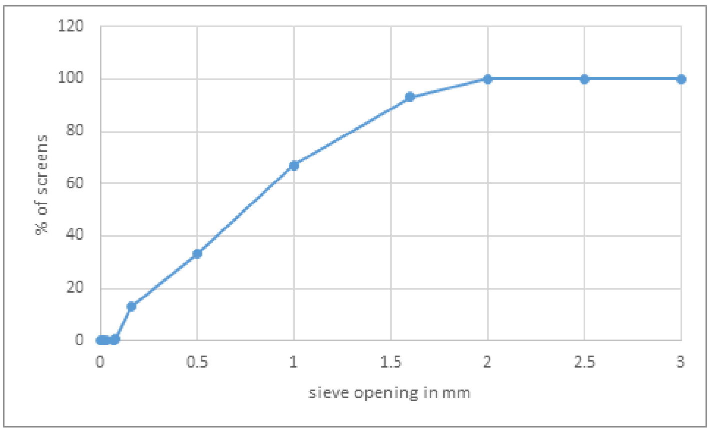

Figure 3 The grain size curve of the standard sand

2.3. Additions used

2.3.1. Adjuvant

The admixture used is SIKAPLAST FLUID 80R, it is a superplasticizer / high water-reducing agent, and it was initially incorporated in the cement paste with a dosage of 1% of the binder to obtain the desired fluidity.

Table N°6 the characteristic table of the adjuvant used

Characteristics	Adjuvant
PH	7
Dry matter in%	41
Content Cl- in %	0,1
Content Na2Oeq in%	1,5
Density	1,2

2.3.2. Silica fume

In this study we used Silica fume Condensil S95 DS it is ultra-fine silica from the silicon or silicon-based alloy manufacturing industry to get concrete more durable and with high mechanical performances they have the form of small spherical particles with an average diameter of about 0.1µm. Their specific surface is in the order of $20m^2/g$.

2.3.3. Limestone fillers

Substitution of cement portions by limestone fillers was proposed to evaluate their effect on the fluidity of the mixture, in our case of sand concrete, limestone fillers are a fundamental component to compensate for the absence of gravel in the case of sand concrete, below the characteristic table of the limestone fillers used in this study:

Table N°7 The characteristic table of the limestone filler

Characteristics	Limestone filler
Granular class (mm)	0-0,063
supericial gloss (m2/Kg)	555
water demand (%)	0,6
Blue value (g/Kg)	0,66
Water content (%)	0,13

2.3.4. Polypropylene fibers

The fibers used are fibers of polypropylene nature which have been manufactured by the textile industry since 1954. Indeed, Polypropylene is a crystallisable polymer of the polyolefin family of chemical products. It has experienced a growing extension in this field where it brings the following advantages: high deformability, rot-resistance and good tensile strength that can reach 800 MPa, at this research study we used the lankofibres type supplied by Sodap:

Table N°8 The characteristic table of polypropylene fiber

Subject	round section	Diameter	length	Eltivation (L/D)	specific weight	tensile strength	elasticity coefficient
Polypropylene fiber	15µ	32µm	12mm	375	0,91g/cm	320 at 400 N/mm2	3,6 KN/mm2

2.3.5. Plastic grains used in soles industry

We have substituted sand proportions with PVC (polyvinyl chloride) plastic grains used in the soles industry, below the picture and the characteristic table of these crushed plastic grains used in the tests.

Table N°9 the characteristic table of plastic grains

Subject	Diameter (mm)	density (g/cm3)	Harshness	tensile strength (MPA)	elongtion at break (%)
Plastic grains	0,33	0,96	55	55	190

3. EXPERIMENTAL PROTOCOL

3.1. Experimental protocol performed on fresh concrete

To characterize the freshly formulated concrete we used a Marsh cone (-NM 10.1.270) coupled with a horizontal Plexiglas channel, the fundamental principle of this study is to determine the influence of the addition of silica smoke or limestone fillers or plastic grains on the optimization of the time of flow while fixing the E/C ratio at 0.5 and the dosage by superplastifiant at 1% of the cement.

The test consists of measuring the time it takes to empty a cone containing 1 liter of binder through a 10 mm diameter discharge opening. This time is 6 seconds for water. Using a mortar mixer, the flow time is measured 5 minutes after starting mixing. The flow time measured is used to assess the flow rate of the binder. The shorter this time, the more fluid the binder and the longer it is, the more viscous the binder.

The formulations studied in the fresh state are as follows:

Table N°10 the different formulations carried out in the fresh state

F1	CPJ55	Sebou sand	water	adjuvant	Silica fume from 10% to 50% of liant
F2	CPJ55	sea sand	water	adjuvant	Silica fume from 10% to 50% of liant
F3	CPJ55	standard sand	water	adjuvant	Silica fume from 10% to 50% of liant
F4	CPJ55	Sebou sand	water	adjuvant	Limestone filler from 10% to 50% of liant
F5	CPJ55	sea sand	water	adjuvant	Limestone filler from 10% to 50% of liant
F6	CPJ55	standard sand	water	adjuvant	Limestone filler from 10% to 50% of liant
F7	CPJ56	Sebou sand	water	adjuvant	Plastic grains 10% to 50% of sand
F8	CPJ57	sea sand	water	adjuvant	Plastic grains 10% to 50% of sand
F9	CPJ58	standard sand	water	adjuvant	Plastic grains 10% to 50% of sand

3.2. Experimental protocol to improve the strength of cured concrete

Mechanical characterization is obtained by using compressive and bending strength measurements on 4x4x16 cm3 specimens conforming to NM EN 1052-2 and NM EN 772-1.

Specimen preparation is carried out in accordance with NM 10.1.068. Mixing is carried out using a concrete mixer with a total mixing time of 3 minutes. The vibration was carried out on a vibrating table with adjustable vibration amplitude. The vibration duration is 30 + 30 seconds. After 24 hours of storage in a humid room, the specimens are stored in saturating humidity (ambient temperature, Humidity=100%), the table below shows the main formulations carried out in mechanical strength tests:

Notes:

- SCT: Sand concrete test
- SCFP: Sand concrete with polypropylene fiber
- SCGP: Sand concrete with plastic grains

Table N°11 The different formulations carried out for the sand concrete studied

Sand concrete	component dosage (Kg/m3)										
	Cement	Limestone filler	Powder (Cement +Limestone filler	Water	Sea Sand	Standard sand	Wadi Sebou sand	Superplatifiant	E/C	Polypropylene Fiber	Plastic grain
SC1T	350	235	585	292,5	1627	-	-	5,85	0,5	-	-
SC2T	350	235	585	292,5	-	1627	-	5,85	0,5	-	-
SC3T	350	235	585	292,5	-	-	1627	5,85	0,5	-	-
SC1FP	347,075	235	582,075	291,0375	1627	-	-	5,82075	0,5	2,925	-
SC2FP	344,15	235	579,15	289,575	1627	-	-	5,7915	0,5	5,85	-
SC3FP	341,225	235	576,225	288,1125	1627	-	-	5,76225	0,5	8,775	-
SC4FP	338,3	235	573,3	286,65	1627	-	-	5,733	0,5	11,7	-
SC5FP	347,075	235	582,075	291,0375	-	1627	-	5,82075	0,5	2,925	-
SC6FP	344,15	235	579,15	289,575	-	1627	-	5,7915	0,5	5,85	-
SC7FP	341,225	235	576,225	288,1125	-	1627	-	5,76225	0,5	8,775	-
SC8FP	338,3	235	573,3	286,65	-	1627	-	5,733	0,5	11,7	-
SC9FP	347,075	235	582,075	291,0375	-	-	1627	5,82075	0,5	2,925	-
SC10FP	344,15	235	579,15	289,575	-	-	1627	5,7915	0,5	5,85	-
SC11FP	341,225	235	576,225	288,1125	-	-	1627	5,76225	0,5	8,775	-
SC12FP	338,3	235	573,3	286,65	-	-	1627	5,733	0,5	11,7	-
SC1GP	350	235	585	292,5	1464,3	-	-	5,85	0,5	-	162,7
SC2GP	350	235	585	292,5	1301,6	-	-	5,85	0,5	-	325,4
SC3GP	350	235	585	292,5	1138,9	-	-	5,85	0,5	-	488,1
SC4GP	350	235	585	292,5	976,2	-	-	5,85	0,5	-	650,8
SC5GP	350	235	585	292,5	-	1464,3	-	5,85	0,5	-	162,7
SC6GP	350	235	585	292,5	-	1301,6	-	5,85	0,5	-	325,4
SC7GP	350	235	585	292,5	-	1138,9	-	5,85	0,5	-	488,1
SC8GP	350	235	585	292,5	-	976,2	-	5,85	0,5	-	650,8
SC9GP	350	235	585	292,5	-	-	1464,3	5,85	0,5	-	162,7
SC10GP	350	235	585	292,5	-	-	1301,6	5,85	0,5	-	325,4
SC11GP	350	235	585	292,5	-	-	1138,9	5,85	0,5	-	488,1
SC12GP	350	235	585	292,5	-	-	976,2	5,85	0,5	-	650,8

4. RESULTS AND DISCUSSION

4.1. Fresh concrete

The graphs below illustrate the evolution of the flow time according to the additives used:

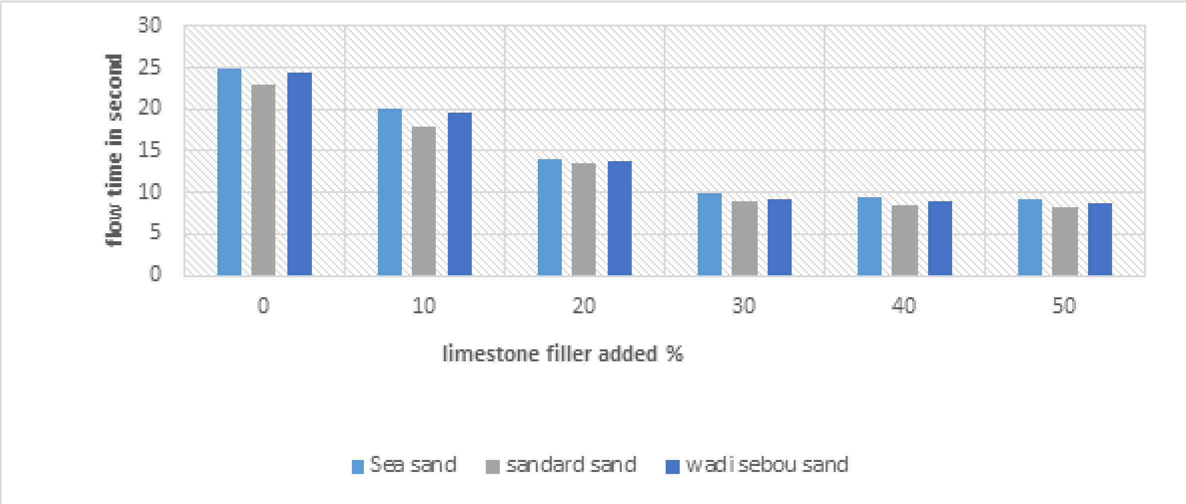

Figure 4 The effect of adding limestone filler on the fluidity of fresh concrete

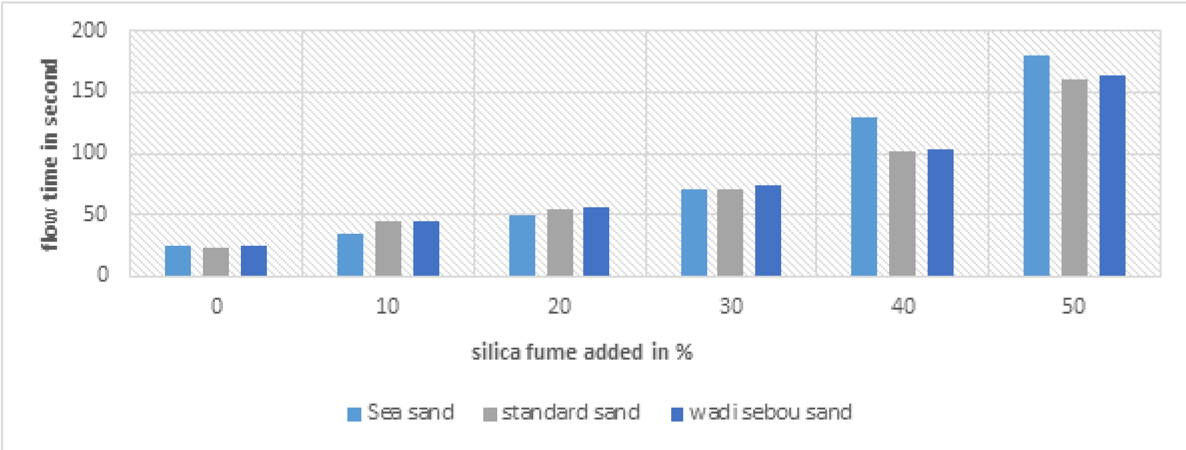

Figure 5 The effect of adding silica fume on the fluidity of fresh concrete

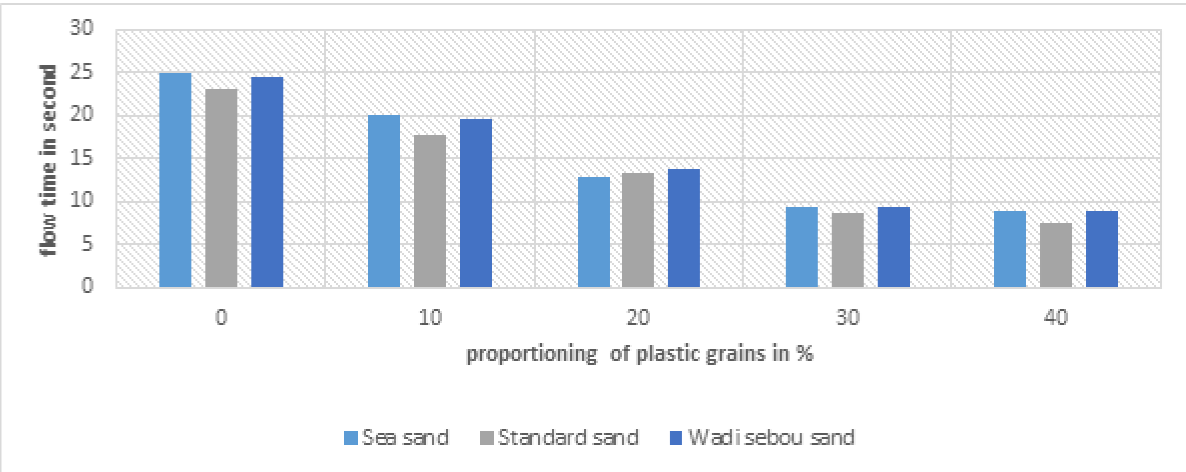

Figure 6 The effect of adding plastic grains on the fluidity of fresh concrete

The graphs illustrate that for high percentages of silica smoke, the fluidity of the designed concrete decreases significantly and we subsequently obtain an increasingly viscous material, this is confirmed by the various research studies carried out on the pozzolanic effect of silica smoke, but several studies have shown that silica smoke contribute radically at improving the material strength. However, the introduction of plastic grains used in soles industry instead of sand improve the fluidity of the mixture which is proved in the graphs by the decreasing of flow time. In addition, the substitution of cement portions by limestone fillers has also a positive impact on fluidity of the binder with a saturation dosage of almost 40% because, beyond this percentage, the addition of fillers has no effect in addition; moreover, the nature of the sand considerably affects the fluidity of the concrete, indeed standardized sand and the river of Sebou sand have the best performance in terms of fluidity compared to sea sand.

In conclusion, it can be said that the tool used, which is of course the Marsh cone (-NM 10.1.270) coupled with a Plexiglas horizontal channel, allows to describe the evolution of the flow time according to the additions, however there are other tools allowing to achieve the same objective such as the L-shaped box.

4.2. Cured concrete

4.2.1. Compressive strength

The graphs below illustrate the evolution of the compressive strength according to the additives used:

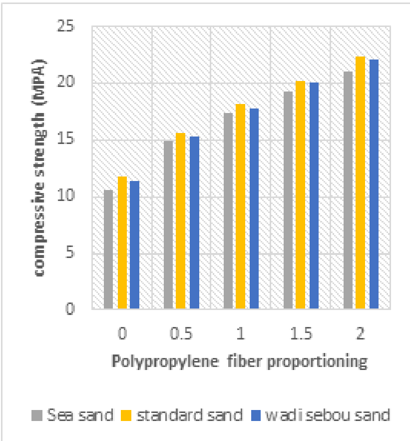

Figure 7 The evolution of concrete compressive strength using polypropylene fibers in 2 days

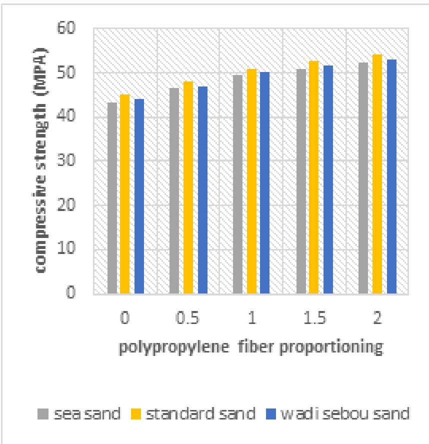

Figure 8 The evolution of concrete compressive strength using polypropylene fibers in 28 days

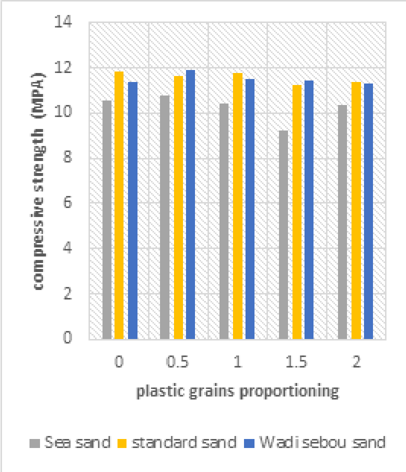

Figure 9 the evolution of concrete compressive strength using plastic grains in 2 days

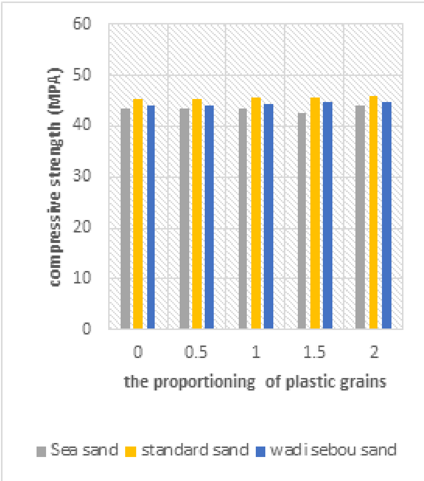

Figure 10 the evolution of concrete compressive strength using plastic grains in 28 days

According to the graphs above we can see that the nature of the sand considerably affects the resistance of the concrete, indeed standard sand used by the Lafarge-Holcim plant has the best mechanical performance followed by sand extracted from the river of Sebou and finally the sea sand has low mechanical compressive strength compared to the other types used.

In addition, each addition of 0.5% polypropylene fibers has allowed an average improvement of 3 MPA in compressive strength at 2 days and 2 MPA at 28 days for the different types of sand used.

Moreover, the use of plastic grains from the soles industry, which is introduced for the first time in the manufacture of high-performance concrete has a negligible effect on the mechanical properties of the concrete produced in fact it has caused small decreases in terms of resistance at 2 days and 28 days, contrary to its positive effect on increasing the fluidity of the mortar.

4.2.2. Bending strength

The graphs below illustrate the evolution of the compressive strength according to the additives used:

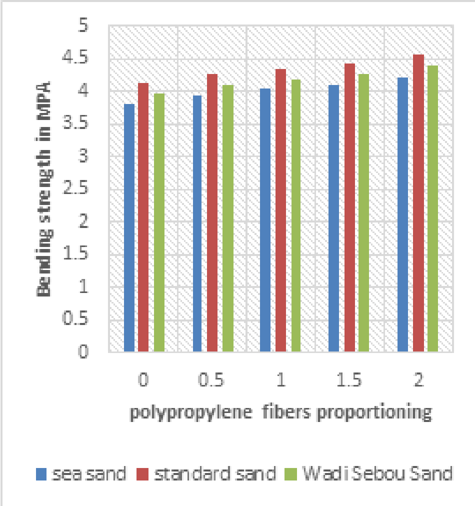

Figure 11 the evolution of concrete bending strength using polypropylene fibers in 2 days

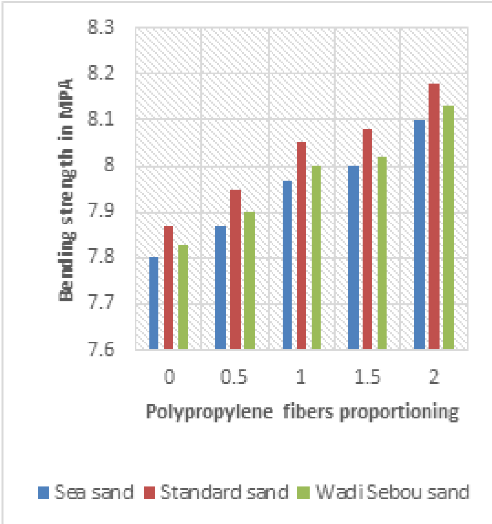

Figure 12 the evolution of concrete bending strength using polypropylene fibers in 28 days

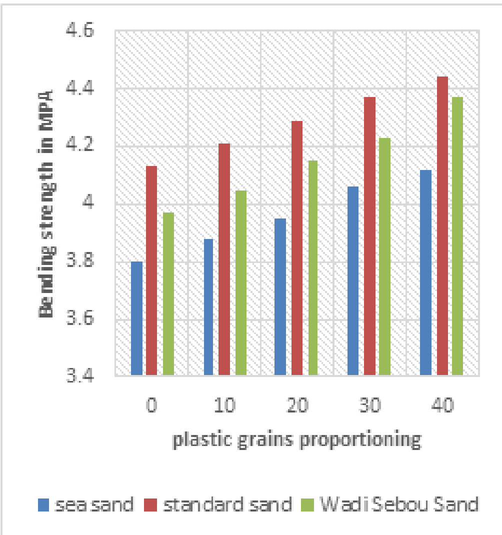

Figure 13 the evolution of concrete bending strength using plastic grains in 2 days

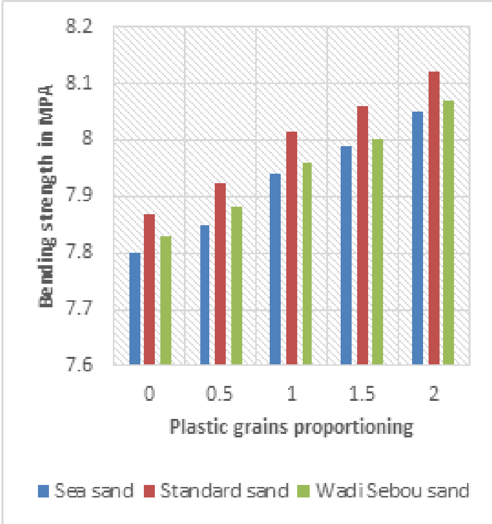

Figure 14 the evolution of concrete bending strength using plastic grains in 28 days

From the graphs above we can see that the incorporation of polypropylene fibers leads to a slight increase in the bending strength of the sand concrete studied, in fact each substitution of 0.5% of the cement by these fibers generates an improvement in the order of 0.2 MPA in bending strength in 2 days and 0.1 MPA in 28 days, in addition, the introduction of plastic grains (PVC) from the sole industry leads to a slight increase in the bending strength of formulated sand concrete, in fact each 10% substitution of sand by these grains leads to an increase of about 0.05 MPA in bending strength in 2 days and 28 days at the same time, finally once again standard sand has the best performance in terms of mechanical resistance to bending followed by sand extracted from the river of Sebou followed by sea sand.

4.2.3. Removal of formulated concretes

The graphs below present the evolution of the removal of the concrete formulated according to the additions and the nature of the sand:

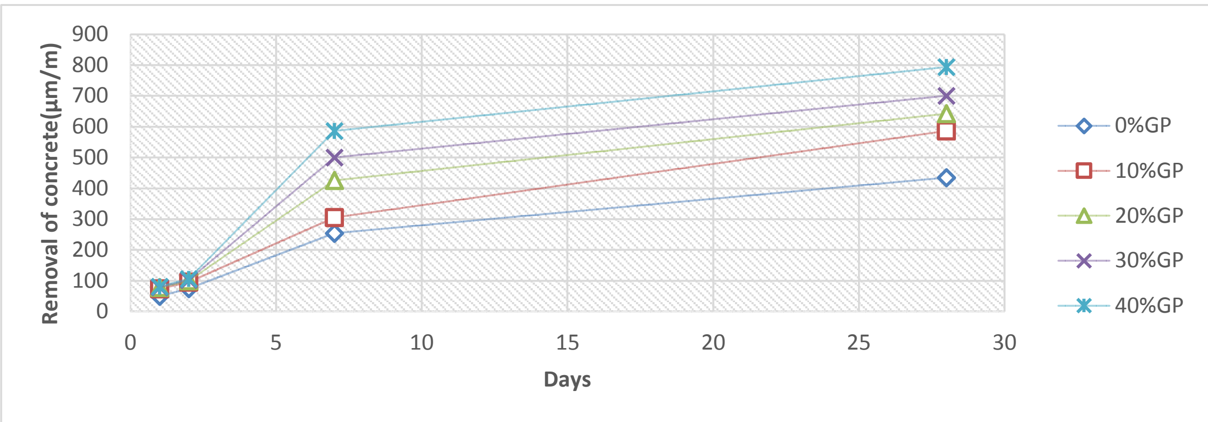

Figure 15 Removal of the river of Sebou sand concrete with plastic grains

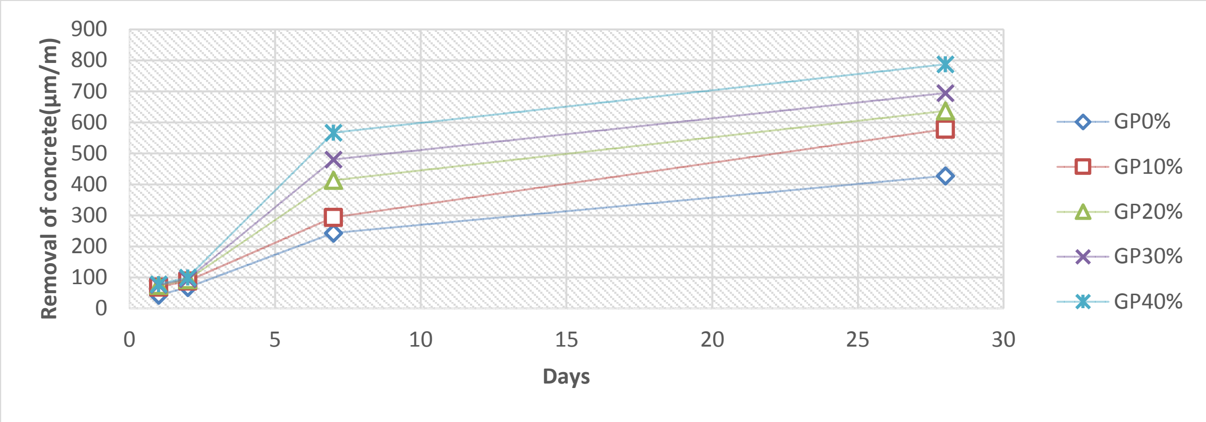

Figure 16 Removal of the standard sand concrete with plastic grains

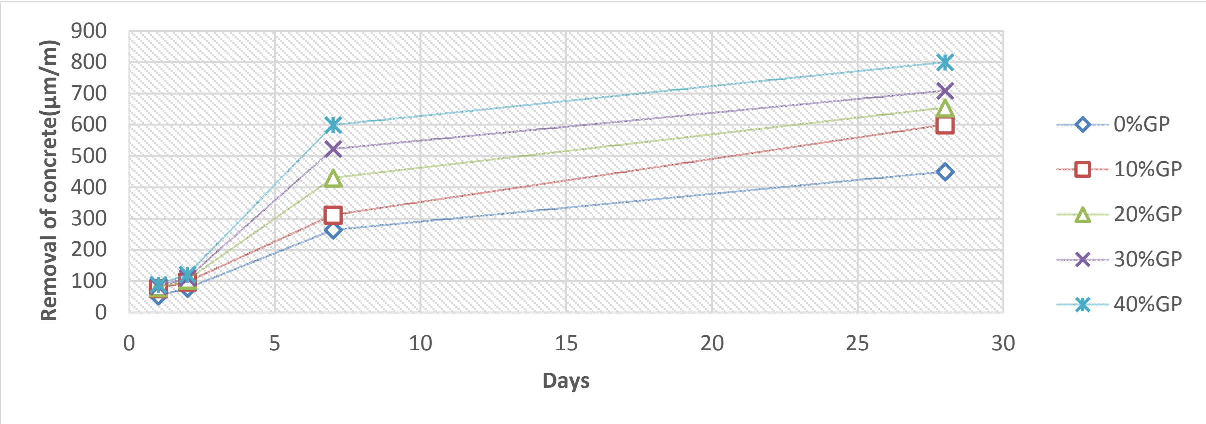

Figure 17 Removal of the sea sand concrete with plastic grains

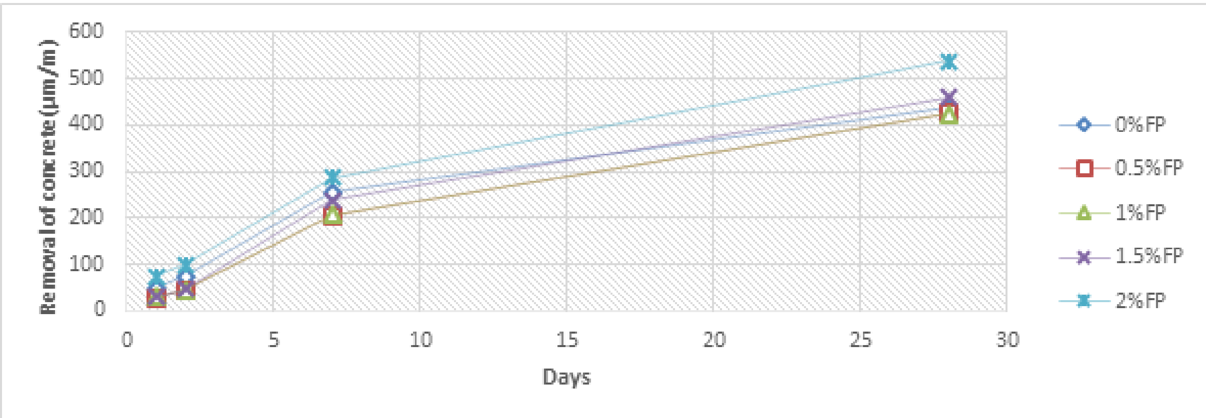

Figure 18 Removal of the river of Sebou sand concrete with polypropylene fiber

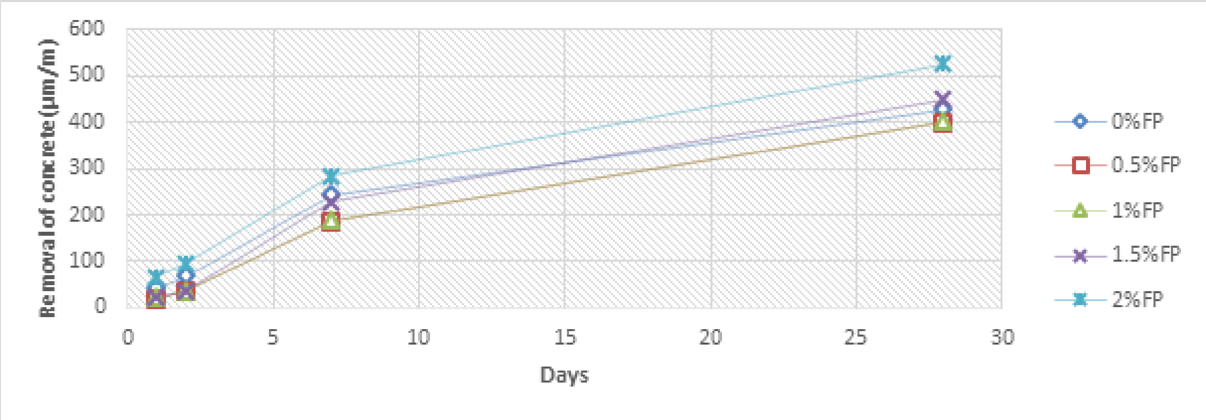

Figure 19 Removal of the standard sand concrete with polypropylene fiber

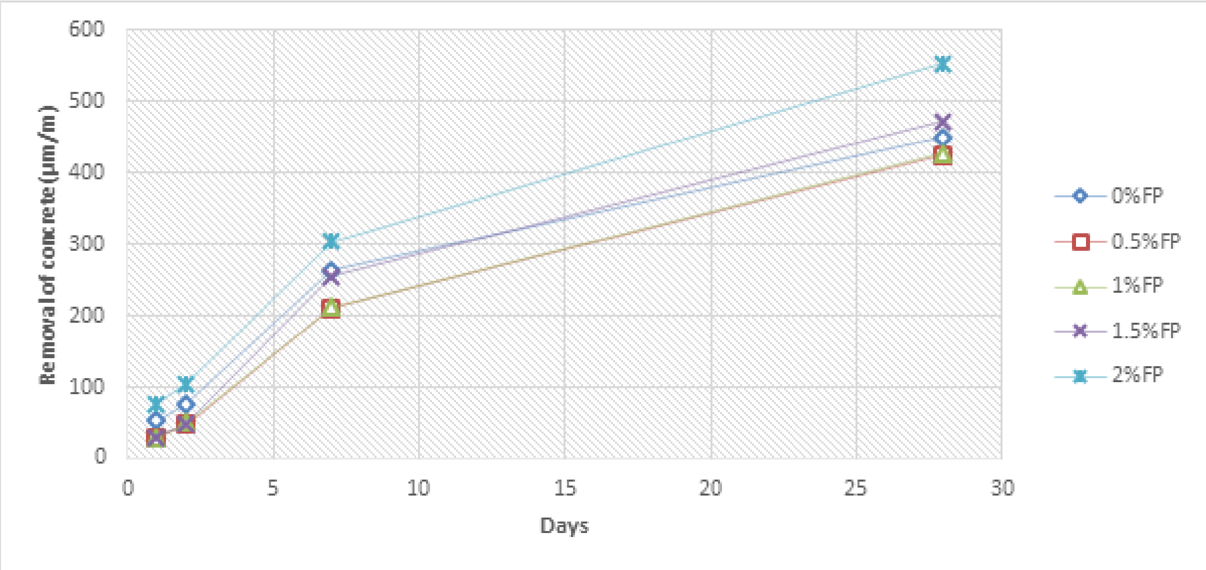

Figure 20 Removal of the sea sand concrete with polypropylene fiber

From the graphs above, according to the appearance of figures 15, 16, 17, the substitution of the proportions of sand by plastic grains used in the sole industry which is used for the first time in the formulation of high performance concretes leads to a greater shrinkage compared to that of control concrete, in fact the more the percentage of addition increases the shrinkage increases in a notable way.

On the other hand, according to figures 18, 19, 20 we notice that the introduction of polypropylene fibers instead of cement proportions with moderate percentages in particular (0.5%, 1%) leads to a notable delay in shrinkage compared to the control concrete whereas from an addition of 1.5% of fibers shrinkage becomes greater than that of the control concrete.

Finally, we note that the nature of the sand has little impact on the shrinkage of the concrete: the three types used show relatively convergent shrinkage values.

5. CONCLUSION

The objective of this work is to seek an optimal formulation of a high-performance concrete that offers both the two qualities required by builders and that are fluidity to facilitate placement and mechanical strength to resist the various agents that threaten the durability of the material designed in the long term.

Generally, we can deduce in the first place that plastic grains offer the best performance in terms of the desired fluidity, but they don't have any effect on the behavior of the concrete in the hardened state, on the contrary they accelerate shrinkage, limestone fillers also contribute significantly to improving the fluidity of concrete, although they are more expensive than the plastic grains used.

Secondly, Polypropylene fibers have proven their crucial role in increasing mechanical compressive strength both in 2 days and 28 days, more than that they contribute to a slight increase in the bending strength of the sand concrete, in addition, a moderate addition of 1 to 1.5% of the polypropylene fibers generates a significant delay in shrinkage compared to the control concrete.

Finally, Standard sand has the best performance in terms of fluidity or resistance followed by sand extracted from the river of Sebou followed by sea sand; concerning the removal we note that the behavior of the different types of sand is similar.

To synthesize the above we propose the following sand concrete formulation that ensures the right combination between fluidity and desired mechanical performance:

Table N°12 the appropriate formulation of the sand concrete studied

Component	Proportioning (Kg/m3)
Cement+Limestone fillers	576,225
The river of Sebou sand	1301,6
Water	288,1125
Adjuvant	5,76225
Polypropylene fiber (1,5%)	8,775
Plastic grains (20%)	325,4

BIBLIOGRAPHY

[1] Bétons de sable (1994), projet national Sablocrete, presses de l'ENPC, Paris.

[2] CHAUVI N J.-J(1991), Béton de sable: approche de la formulation, Séminaire Francosoviétique sur les bétons de sable, SABLOCRETE, Bordeaux, pp. 62-70.

[3] Jean pierre Olivier, AngéliqueVichot, La durabilité des bétons, Presses de l'ENPC, Paris.

[4] Malier Y., «Les BHP: caractérisation, durabilité et applications». Presse de 1'E.N.P.C, Paris, 1992.

[5] Joumana Yammine. Rhéologie des bétons fluides à hautes performances: relations entre formulations, proprieties rhéologiques, physico-chimie et propriétés mécaniques. Matériaux. École normale supérieure de Cachan - ENS Cachan, 2007. Français.

[6] Ben Amara. D., « Formulation et comportement d'un béton de sable de la région de Biskra renforce de fibre métallique », mémoire de magister, Université de Annaba, Algérie, (2002).

[7] A. Zenati. K. Arroudj. M. Lanez. Influence of cementitious additions on rheological and mechanical properties of reactive powder concretes, Physics Procedia, Volume 2, Issue 3, November 2009, Pages 1255-1261

[8] N. Roussel: Steady and transient flow behavior of fresh cement pastes. Cement and Concrete Research, 35(9):1656–1664, 2005.

[9] Carlsward et al., Effect of constituents on the workability and rheology of selfcompacting concrete, Proceedings of the third international RILEM conference on SCC, août 2003, Reykjavik, Islande, pp 143-153.

[10] Choix des formulations des bétons de references, Thèse de doctorat, INSA, Toulouse, France, 201p. Commene J.P. (2001),

[11] Manaseer.A.A, T. R. Dalal. «Concrete containing plastic aggregates». Concrete International, 1997, PP 47 –52.

[12] Sidharth Sen and K. Balakrishna Rao, Effect of Water Cement Ratio on the Workability and Strength of Low Strength Quarry Dust Concrete. International Journal of Civil Engineering and Technology, 8(10), 2017, pp. 1448–1455.

[13] R.L.Lija and S. Minu, Workability and Strength Behaviour of Self Compacting Concrete with Silica Fume and Marble Sawing Waste. International Journal of Civil Engineering and Technology, 7(4), 2016, pp.474–482

[14] V.S.Tamilarasan, Dr.P.Perumal and J.Maheswaran , Workability Studies On Concrete With Ggbs As A Replacement Material For Cement With And Without Superplasticiser, Volume 3, Issue 2, July-December (2012), pp. 11-21, IJARET

[15] Lionel Moreillon. Shear strength of structural elements in high performance fiber reinforced concrete (HPFRC). Other. UniversitéParis-Est, 2013. English.