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Effect of Adding Recycled Sand and Fines Retained from Eggshell Waste on the Mechanical Properties and Durability of SCC and SFSCC

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HIGHLIGHTS

- Valorization of crushed demolition waste mainly that of concrete (recycled sand).
- Valorization of eggshell waste.
- Realizer an eco-self-compacting.
- Addition of eggshell fines in adequate quantity, can improve the properties of SCCs.
- Using recycled sand did not contribute to a significant effect on the mechanical properties of the mixtures studied.

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ABSTRACT

This scientific research was carried out within the framework of contributing to the recovery different of natures of waste, and making it possible to minimize using of natural aggregates in the field of construction, in order to place an eco-self-consolidating concrete (eco-SCC). Crushed demolition waste mainly of concrete had been studied as a substitute for natural sand. As well as the effect of replacing fines with crushed eggshell waste was assessed. So this present work fits in these contexts. Therefore the main objective of this study is to improve current knowledge on the behavior of studied concretes in the fresh state: slump-flow test, and hardened state: mechanical resistances in compression and in bending, as well as water absorption by capillarity test, absorption by total immersion, and porosity accessible to the water of SCCs designed from different types of waste, recycled sand, and eggshell fines. Also, the method of assessing mixes were affected by the sort of chemical attack, namely the (NaCl) attack was investigated. In light of the obtained results, it was found that the addition of eggshell fines in adequate quantity, can improve the properties of SCCs, in this study a volume of 30% was sufficient, increasing the volume added to 60% introduced an opposite effect. Using recycled sand in this study did not contribute to a significant effect on the mechanical properties of the mixtures studied, although an improvement in workability was observed.

1. Introduction

Concrete has long been used as a building material, it is now the most commonly used and the second most consumed material in the world after water. This composite has become crucial in the field of civil engineering globe, and this is because of its mechanical properties. It can sustain high compressive loads (up to 100MPa). Then, it must adhere to stricter rules for workability, shapes, and sustainability. The history of the use of this material is marked by a succession of inventions and patents. Current progress has allowed the emergence of special concretes, such as self-consolidating concrete [1].

The great fluidity of self-consolidating concrete, also known as self-leveling concrete or self-compacting concrete, sets it apart from other kinds of concrete. It is an attribute that has long been sought after in the field of construction, to facilitate the implementation of concrete on construction sites. Water is frequently added to the mixture to make the concrete more fluid, but this weakened it. This is why the SCC is a real revolution. It first appeared in Japan in the 1980s before developing in France towards the end of the 1990s [2, 3].

Self-consolidating concrete's fluidity is an outcome of the way it is made; in comparison to regular concrete, self-compacting concrete contains more powder content (cement + fines + water + superplasticizers). The aggregates and fines used are generally derived from natural rocks. These aggregates' available stock tends to decline and can no longer satisfy this demand. The demand for building materials has expanded along with the infrastructure's rapid growth [4,5]. One of the most popular types of additives worldwide is substantially inert. The use of trash as a partial or whole replacement represents one of the workable alternatives accessible, as a result of the considerable ecological issues that CO_2 emissions have generated. The recycling of demolition waste serves as a viable option for using other sources of replacement [6-8].

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Eggshell trash seems to be another alternative for replacing the substantial amount of fines required in SCC buildings. Every day, tons of eggshells, which are composed of a ratio of 97% of calcite ($CaCO_3$), are released into the environment [9]. These wastes might work well as building material substitutes [10-16]. Environmental impacts brought on by open garbage dumping can be lessened by the conversion of replacement waste. Eggshell is a waste product that can be obtained in bakeries, restaurants, and residences. A chance for a long-term fix might arise if viable use for eggshells could be developed. Eggshell fines are a finely divided material, frequently with a fineness of less than 80 µm, used in the formulation of hydraulic concretes, and are used as a mineral additive for concrete. During the manufacturing process, it is mixed into concrete to enhance certain of its qualities: workability, and consistency, or to give it particular qualities: compactness, durability, and resistance to adverse conditions [9, 10, 13, 15, 17].

The replacement of filler by eggshell powder leads to the development of resistance compared to the control. Several studies have shown the potential of using eggshell powder, combined with fillers in appropriate dosages in the formulation of concretes, to improve the flow properties of fresh concrete and the mechanical strength of concrete hardened. Therefore, the eggshell powder offers a cost-effective and energy-efficient answer to the problem of sustainable building materials [13-15].

Sand plays a very important role during the manufacture of concrete because it influences both the properties of concrete in its fresh state, the mechanical resistance, and durability. To produce affordable and long-lasting concretes, it is now required to be concerned about the use of manufactured sands, recycled sands, dune sands, or sea sands [18, 19]. Such as:

- Satisfy the increasing demand for aggregates;
- Protect the environment by preventing the improper dumping of debris and by limiting the exploitation of quarry and river aggregates.
- Assist in the development of recycled aggregates.
- Participate in investigations on the use of recycled aggregates in place of natural aggregates in concrete.

This work aims to contribute to the recovery of demolition materials, mainly concrete as a substitute for natural sands as part of the development of an eco-SCC. It would also be beneficial, to reduce the use of fines of natural origin, so the use of crushed eggshell waste in place of fines, to enable the production of new SCC will also be evaluated. This work fits in this context, it has then for main objective is the improvement of the current knowledge on the behavior in the fresh and hardened state as well as the durability of the SCCs designed based on a different type of waste, recycled sand and eggshells fine.

2. Experimental Work

2.1 Materials

It is vital to determine the components employed before beginning a concrete formulation, the main characteristics are taken from the technical sheets drawn up at the level of the companies producing these materials.

The cement used is CPJ-CEMII/A 42.5 with true strength of 43.31 Mpa, from the cements plant GICA (Algerienne Cement Industrial Group) in Hamma Bouziane, East Algeria; it complies with the Algerian standard NA 442 and NF EN 1971. It contains at least 80% clinker, at most 15% standard additives and most 5% gypsum. It is characterized by an onset of setting at 2h and an end of setting at 3h. Its fineness is 3895cm²/g.

Limestone Filler class FU10 is an aggregate composed of elements of very small dimensions; from the ENG (National Aggregates Company) Giant-Quarry in Constantine, East Algeria. Manufactured according to standard NF P 18 508. 98% of filler FU10 elements have a diameter of less than 100µm. It is used in concrete to increase its compactness.

Aggregates as crushed materials of granular classes: sand (0-4) and gravel of classes (4-8, 8-15) from the ENG in Constantine, East Algeria. Regular drinking water supplied to laboratory LMSS characterized by a PH of 7.6.

The superplasticizer used in this study is Master Glenium 26; its dosage is 0.3 to 2.0% of the weight of the cement. It is conformed to ASTM C-494 Type F and G and BS EN 934-2.

2.1.1 Waste eggshells

In this research, eggshells Table 1 were added in replacement of the filler at a rate of 30%–60%. Its fineness is equal to that of the limestone filler. These fines gave a refusal of 27% on the 80 µm sieve.

Table 1: Physical properties of eggshell [13]

Nom	Properties
Specific gravity	0.85
Humidity content	1.18
Apparent density (g/m^3)	0.8
Particle density (g/m^3)	1.012
Porosity(%)	22.4 (BET)
Surface air (m^2/g)	21.2

In order to eliminate and decrease impurities, the egg shells that were salvaged from pastry waste Figure 1 (a) were first rinsed with water. Then it was dried for 4 hours at 105°C. After that, the eggshell was crushed Figure 1 (b) and then ground Figure 1 (c). Figure 1 shows the several steps in the manufacture of eggshells as tiny particles:

(a) **(b)** **(c)**

Figure 1: a) Eggshell waste, b) crushed eggshell, c) crushing eggshell and obtaining fine eggshell particles

2.1.2 Identification of the investigated sands

Two different types of sand were employed in this study.

- Recycle sand Figure 2 (b): An essential component of this study, which was obtained by grinding the debris from the concrete specimens Figure 2 (a) analyzed in this the laboratory of LMSS.
- Natural sand Figure 2 (C): Was obtained from the enormous ENG quarry.

(a) **(b)** **(c)**

Figure 2: Preparation of recycled sand: a) crushed concrete, b) obtaining recycled sand c) natural sand

The results of the particle size analysis of natural sand and recycled sand are generated and illustrated in Figure 3 below:

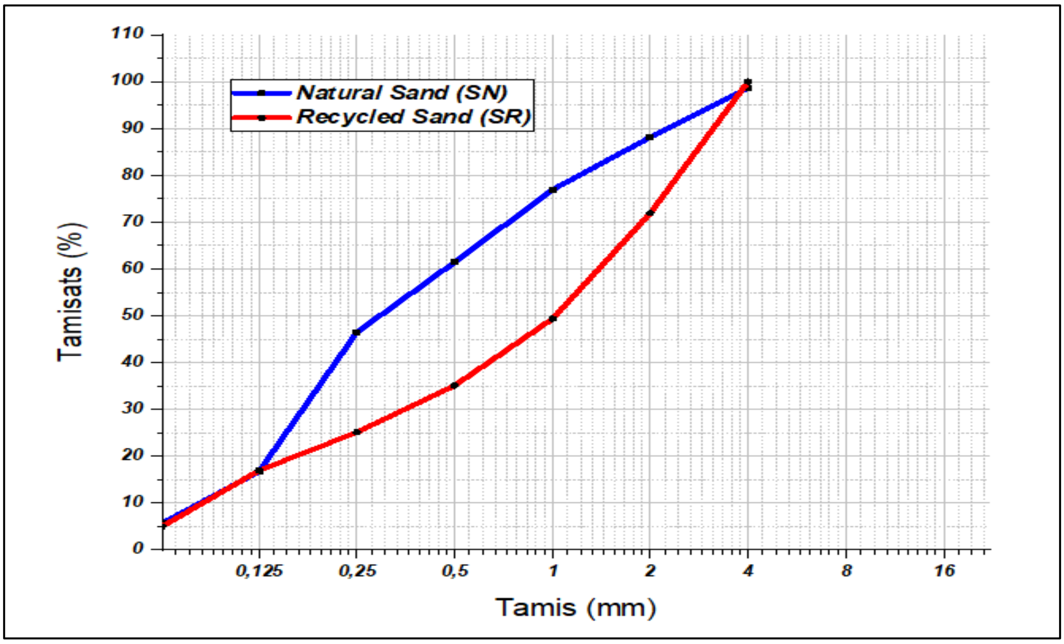


Figure 3: Granulometry of natural sand and recycled sand

The fineness modulus (FM) of studied sands expressed as a percentage [NF P18-304]:

- Natural sand has FM=3.008; as a result, the sand that is present is preferable.
- Recycled sand has an FM of 2.11, making the majority of the grain fine.

The cleanliness test for recycled sand was also carried out [NF P18-591]. A result of 1.2% of particles of 0.5mm was obtained, lower than 5%, it is then concluded that the recycled sand obtained is clean.

2.1.3 Fibers

FIBRTEK A produced from trefoil steel wire, are the metal fibers that are employed in Table 2. They include a mechanical inking consisting of hooks at the ends, characterized by an aspect ratio (L_f/d_f) of 50.

Table 2: Geometrical and physical characteristics of steel fibers

Nature	Drawn steel wire without coating
Length (mm)	50 (+/-) 10%
Diameter (mm)	1 (+/-) 10%
Slenderness	50
Number of fibers	2800 fibre/kg
Tensile strength	1000Mpa (sur fil)
Fusing temperature	1380°C
Volumic mass (kg/ dm3)	7.85

2.2 Method

2.2.1 Mixes

The choice of concrete has focused on self-consolidating concrete (SCC) and self-consolidating concrete reinforced with steel fibers (SFSCC). The mixtures studied in this present work are illustrated in Table 3 below:

Table 3: Series of mixtures studied

Concrete	Designation
BAP	Mixture of SCC made with 100% natural aggregates
BAP SR	Mixture SCC made with 70% natural aggregates and 30% recycled sand
BAP F	Mixture of SCC made with 100% natural aggregates, reinforced with 0.6% steel fibers
BAP SR F	Mixture of SCC made with 70% natural aggregates and 30% recycled sand, reinforced with 0.5% steel fibers
BAP CO30%	Mixture of SCC made with 100% natural aggregates and 30% eggshells as a substitute for Filler FU10
BAP CO60%	Mixture of SCC made with 100% natural aggregates and 60% eggshells as a substitute for Filler FU10
BAPF CO30 %	Mixture of SCC made with 100% natural aggregates and 30% eggshells as a substitute for Filler FU10, reinforced with 0.6% steel fibers
BAPF CO60%	Mixture of SCC made with 100% natural aggregates and 60% eggshells as a substitute for Filler FU10, reinforced with 0.6% steel fibers.

The fiber content per cubic meter of concrete was 0.6%. The compositions for 1 M3 of the mixtures studied are presented in Table 4 below:

Table 4: Compositions of tested mixtures

	Cement (kg)	Filler Fu 10(kg)	Sand N (kg)	Sand RC (kg)	Gravel (3/8) (kg)	Gravel (8/15) (kg)	Fiber (kg)	Water (kg)	Super-plasticizer (kg)
BAP	400	100	737.94	/	368.97	368.97	/	185.41	10.41
BAP SR	400	100	516.69	221.25	368.97	368.97	/	185.41	10.41
BAP F	400	100	737.94	/	368.97	348.96	50	185.41	10.41
BAPF SR	400	100	516.69	221.25	368.97	348.96	50	185.41	10.41
BAP CO30%	400	70	737.94	/	368.97	368.97	/	185.41	10.41
BAP CO60%	400	40	737.94	/	368.97	368.97	/	185.41	10.41
BAPF CO30 %	400	70	737.94	/	368.97	348.96	50	185.41	10.41
BAPF CO60%	400	40	737.94	/	368.97	348.96	50	185.41	10.41

2.2.2 Fresh concrete test

A non-exhaustive list of tests for characterizing the properties of concretes in the fresh state is recommended by the French Association of Civil Engineering (AFGC 2000). However, in this study the characterization in the fresh state of SCC was limited to the slump-flow test, which is used to characterize the fluidity of self-compacting concrete in an unconfined environment.

A target value of around 750 mm for the BAP (controls) corresponds to the recommended average spread of an SCC.

2.2.3 Hardened concrete tests

The mechanical resistances in compression [NF EN 12390-3] and bending [NF EN 12390-5] are essential characteristics of the concretes, and fundamental parameters of this study, consequently their evolution was followed for all the studied concrete. The tested specimens were placed in different molds intended for the test bodies corresponding to the scheduled tests: Cubic specimen: 10×10x10cm, and prismatic slenderness specimen: 7×7×28cm.

2.2.4 Durability characteristics tests

A material's capacity to absorb and hold water is referred to as its water absorption capacity. It aids in illuminating the other durability traits. Two water absorption tests were carried out: absorption by total immersion, and absorption by capillary suction.

2.2.5 Water absorption by capillarity test

The capillary water absorption test (Figure 4), is a test that provides information on the water absorption capacity in a concrete by capillary rise. The capillarity absorption coefficient can be determined according to [NBN B 15-215:1989] by the following Equation:

$$Ca\,t = \frac{Mt - M0}{A} \tag{1}$$

- Cat: Absorption coefficient at time t (g/mm^2).
- Mt: Mass of the specimen at a given time (g).
- M0: Initial mass of the specimen (g).
- A: Section of the specimen in contact with water (mm^2).

Figure 4: Water absorption by capillarity test

2.2.5.1 Absorption by total immersion

The principle of the test consists in determining the variation of the mass of a sample of concrete immersed in a tank of water. The water absorption by immersion (AW) is calculated according to [NBN B 15-21] by the following relationship:

$$AW = \frac{M1 - M2}{M2} \times 100 \tag{2}$$

2.2.5.2 Porosity accessible to water

The basic idea behind the measurement consists in determining the part of the void that is contained in the material in the hardened state. By hydrostatic weighing Figure 5.

It is possible to establish the material's water porosity, what these measurements reveal is [(AFPC-AFREM, 1998) and (NF P 18 – 459)]:

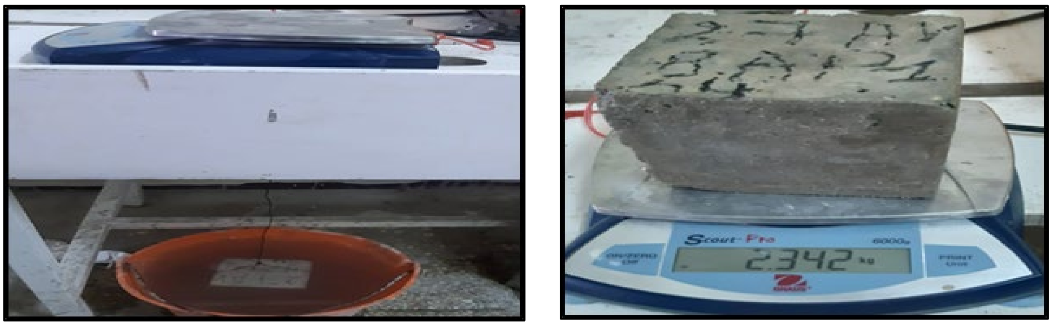
- Apparent density ρd (in kg/m^3) is given by the Equation:

$$\rho d = \frac{Msec}{Mair - Mw} \times \rho w \tag{3}$$

- Porosity accessible to water 'Ɛ', expressed in volumetric percentage, is given by the Equation :

$$Ɛ\,(\%) = \frac{Mair - Msec}{Mair - Mw} \times 100 \tag{4}$$

With: Mair: Mass (g) of the test specimen saturated with water weighed in air, Mw: Mass (g) of the test specimen saturated with water weighed in water, Msec: Mass (g) of the dry specimen weighed in air and ρd : Density of water (kg/m^3).



a) Hydrostatic weighing b) Weighing in the open air

Figure 5: Determination of the porosity of SCC specimens

2.2.5.3 Mode of action of aggressive environments

This study investigates how the assessed mixes were affected by the sort of chemical attack, namely the NaCl attack. Prior to the test, all samples were kept in a chamber at 20°C. The size of the samples used in this investigation is 7x7x28cm, and 10x10x10 cm cubic test containers Figure 6.

Following a technique for concrete aging acceleration based on the following 24-hour immersion/drying cycles:

- Submerging the samples for four hours in saline solution (3% by mass)
- 20 hours of drying in the oven (60°).

Figure 6: Samples placed in the saline solution: a) Immersion of the specimens b) Drying in the oven at 60°

After the samples are removed from the oven, they are immediately weighed using a scale. They are then submerged in the saline solution after cooling.

The evaluation will be done by quantifying the samples' loss of mass in the manner described below:

$$Mass\ variation\ (\%) = [(M2 - M1)/M2)]\ x\ 100 \quad (5)$$

Where M1 is the mass of the specimen before immersion and M2 is the mass of the cleaned and dried specimen after immersion.

3. Results and Discussion

3.1 Fresh Concrete Properties

Figure 7 and Table 5 summarize the experimental results of the workability tests, carried out for fresh self-compacting concrete. The Dm factor represents the average final diameter in the flow test.

According to the results obtained from the slump-flow test, it was found that the spreading measured for the various SCC mixtures studied respects the spreading criterion, according to the AFGC standard between (550 - 850 mm), and their spreading then qualifies them as self-consolidating. All the mixtures studied gave homogeneous patties; no sign of bleeding was noticed. A decrease in workability is observed by adding the hooked steel fibers for all the mixtures studied [1, 20, and 21].

Table 5: Slump-flow test results

Concrete	BAP	BAPCO 30%	BAPCO 60%	BAPF	BAPF CO30%	BAPFCO 60%	BAP SR	BAPF SR
Dm (cm)	74	73.5	79	73	65.5	75	79.5	67

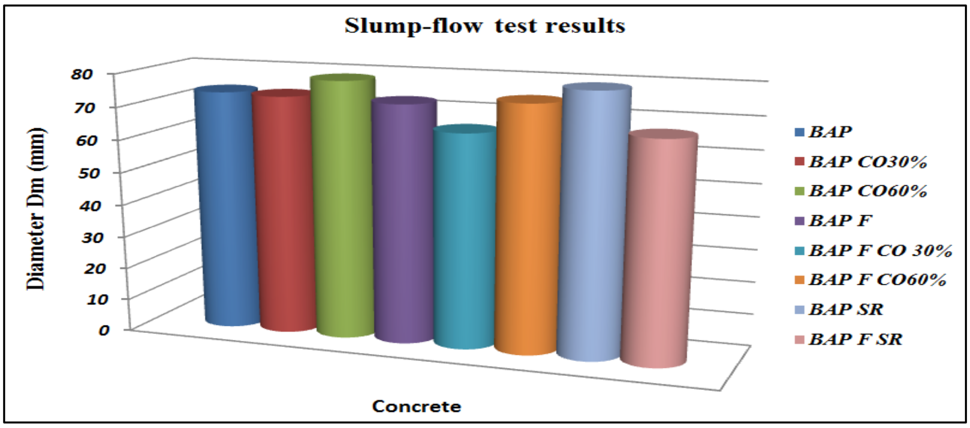


Figure 7: Slump-flow test results of studied SCCs

The introduction of recycled sand in the composition of SCCs has led to an improvement in its workability. An increase in the spreading of the SCC SR compared to that of the reference SCC. It can be justified by the original compositions of the various ground concretes, which may contain additions that have contributed to improving the fluidity of the SCC in this study. However, further work in this subject is recommended.

The mixture containing eggshells at 30% (BAP CO 30%) volume exhibited a similar spread to that of the reference one which contains 100% Filler FU 10. An increase in spreading proportional to the rate of substitution in fines of eggshells was singled out. This increase is due to a tendency of the eggshells to absorb less mixing water than in the case of the Filler [14].

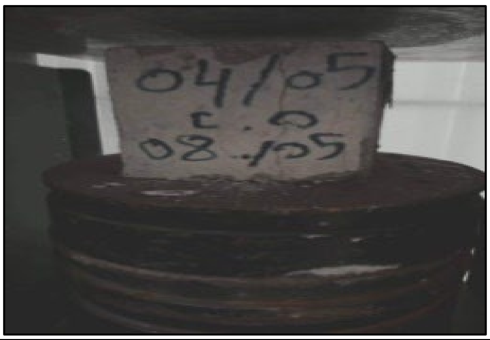
3.2 Mechanical Performance

3.2.1 Compressive strength

The compressive strength was studied at the age of 28 days, after preservation of the samples in the air, the results are presented in Table 6 and Figure 8:

Table 6: Compressive strength results

	BAP	BAPCO 30%	BAPCO 60%	BAPF	BAPFCO 30%	BAPFCO 60%	BAPSR	BAPFSR
Compressive strength (MPa)	39.68	37.88	23.14	30.59	32.04	22.36	34.87	21.48



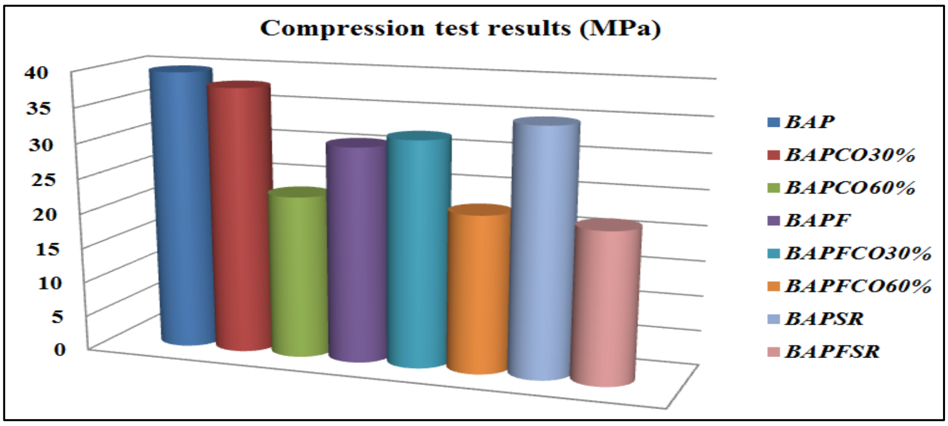


Figure 8: Compression test results of studied SCCs

A decrease in the compressive strength was observed for all the mixtures studied by comparing them to the reference.

A reduction of 11% in the compressive strength with the substitution of 30% of natural sand with recycled sand was recorded; this substitution led to deterioration in the compactness of the SCC with recycle sand mixed (BAP SR) compared to that of the reference SCC produced with natural sand, and consequently a decrease in resistance was observed [8].

A substantial change in the compressive strength of SCC was not observed when the UF 10 filler was replaced by 30% eggshell fines, a slight reduction of 3.54% was observed [14]. However, increasing this substitution to 60% significantly reduced the compressive strength of (BAP CO 60%), a decrease of 40.68% was measured. Eggshell fines are waste whose particles have a smooth surface which does not ensure perfect adhesion with the cement hydrates compared with the particles of limestone filler. It led to a change in the compactness of the cementitious matrix, when added by volume of 60% this negatively influenced the characteristic compressive strength of SCCs.

A negative effect was recorded with the addition of fibers in SCC mixtures, this effect is greater in the case of recycled sand, and a reduction of 38.4% was measured. On the whole, the steel fibers did not allow good fiber-cementitious matrix adhesion, which led to the degradation of the compressive strengths of the fiber-reinforced mixtures.

3.2.2 Tensile test

The results of tensile testing at age 28 are shown Table 7 and Figure 9.

Table 7: Tensile test results

	BAP	BAPCO 30%	BAPCO 60%	BAPF	BAPFCO 30%	BAPFCO 60%	BAPSR	BAPFSR
Tensile strength (N)	5.79	7.72	4.85	5.21	6.67	5.48	6.1	7.35

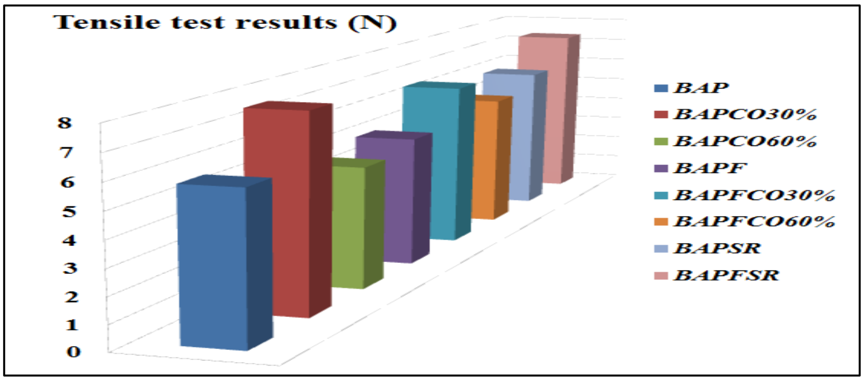


Figure 9: Tensile test results of studied SCCs

The result of the tensile strength obtained for the (BAP SR) is similar to that obtained by the reference SCC. The tensile strength has been significantly increased with the substitution of limestone filler of 30% eggshell. On the other hand, the increase in this substitution to 60% negatively influenced the tensile strength in the (BAP CO60%), the smooth surface of the grains of the eggshells led to a loss of adhesion matrix-aggregates, this which led reducing resistance.

In all the results of tensile strength of the mixtures reinforced with steel fibers, a positive effect of the addition of fibers was distinguished; however the best result was recorded for the case of (BAPF SR). With ductile fracture of the specimens was observed [1, 20, and 21].

3.3 Durability

The durability of concrete is not one of its characteristics, but rather its response to service loads and environmental conditions.

3.3.1 Water absorption

Water absorption capacity is the ability of a material to absorb and retain water. It helps to explain the other durability characteristics. Two water absorption tests were carried out, namely absorption by total immersion and absorption by capillary suction.

3.3.1.1 Absorption by total immersion

The results of the total immersion water absorption tests are shown in Table 8 and Figure 10.

Table 8: Results of water absorption tests by total immersion

	BAP	BAP CO 30%	BAP CO 60%	BAP SR	BAPF	BAPF CO30%	BAPF CO60%	BAPF SR
AW (%)	2 .088	1.248	2.140	1.653	1.156	2.136	2 .504	1.673

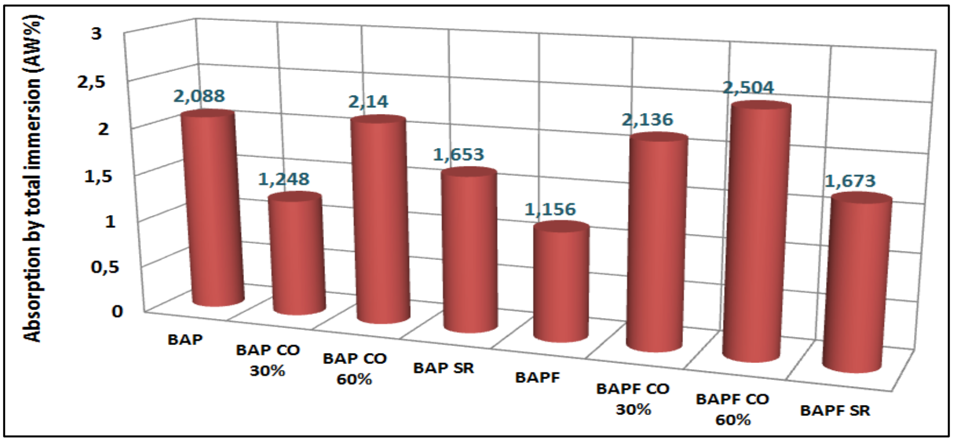


Figure 10: Results of water absorption tests by total immersion

Using 30% of recycled sand in the SCC led to a decrease in the water absorption capacity. The addition of fibers to the mixture of SCC with recycled sand (BAPF SR) did not contribute to an additional effect on its water absorption capacity.

It was found that the addition of eggshell fines in adequate quantity, can improve the properties of SCCs. The presence of 30% eggshell fines in BAP (BAP CO30%) decreased its total water absorption capacity, increasing this substitution to 60% attributed to increasing this capacity. The addition of hooked steel fibers in these blends led to a further increase in the ability of these materials to absorb water, this can be explained by the disorder caused by the presence of steel fibers on the porosity of BAPF CO3% and BAPF CO60%. However, further work in this subject is recommended, with studding other densities of recycled sand, eggshell fines and steel fibers.

3.3.1.2 Absorption of water by capillary action

The results of the tests carried out on cubic specimens (10x10x10cm) subjected to unidirectional water absorption are shown in Figure 11:

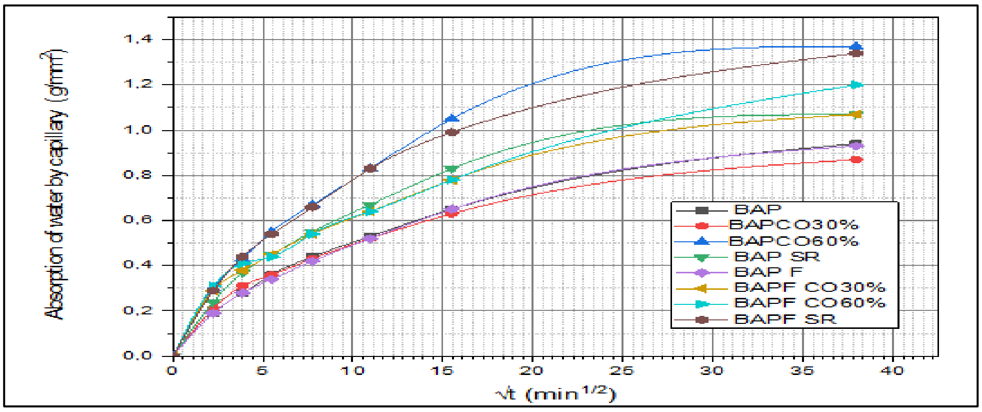


Figure 11: Capillary water absorption test results

The measurements used show an increase in water absorption capacity over time for all the studied mixtures of SCCs. We also note that it is clearly visible that the water absorption is greater for BAPCO 60% and BAPF SR compared to the other mixtures. This high water absorption value is related to the particle size of the recycled sand used in this study.

Using 30% of fine eggshells contributed to a slight decrease in the water absorption capacity by capillarity of BAPCO 30%, it can be said that these composites are the most compact compared to other mixtures studied in this work. The addition of fibers generally led to an increase the water absorption of the various mixtures studied.

3.3.2 Porosity accessible to water

The results of the measurements of the porosity accessible to water for the various composites studied have been gathered in Figure 12.

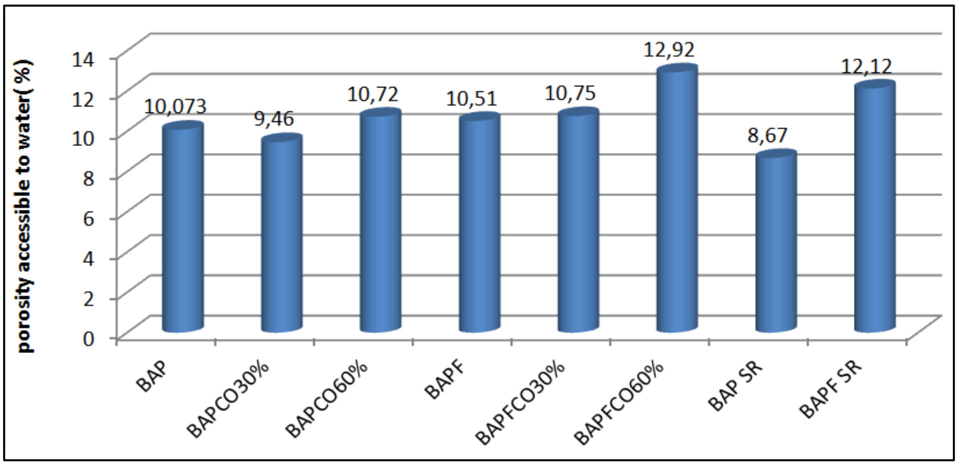


Figure 12: Values of the porosity accessible to water for studied concretes

From the results illustrated above, it was distinguished that the addition of hooked steel fibers negatively influenced the porous structure of the mixtures studied; an increase in porosity was recorded for all the SFSCCs. Addition steel fibers had caused a modification in the structure of the SCCs in the zones of aggregate-fiber interaction, from which an additional porosity is distinguished, however more in-depth studies are recommended.

The results also showed that the eggshell fines led to a reduction in the compactness of the (BAP CO60%) compared to the reference concrete, however the use of 30% fine eggshell allowed a positive effect on the porosity of (BAP CO30%) composites [14]. Same findings concerning (BAP SR), the porosity of this material is linked to the grain size of the recycled sand used for the manufacture of the test specimens, it contains less coarse grains than those of natural sand (see Figure 3).

3.3.3 Volume Mass

The measurements of the density for the examined composites are presented Figure13.

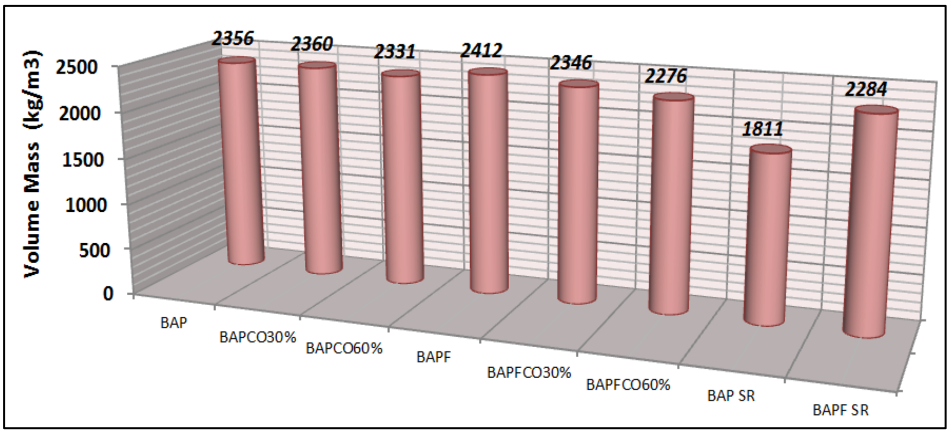
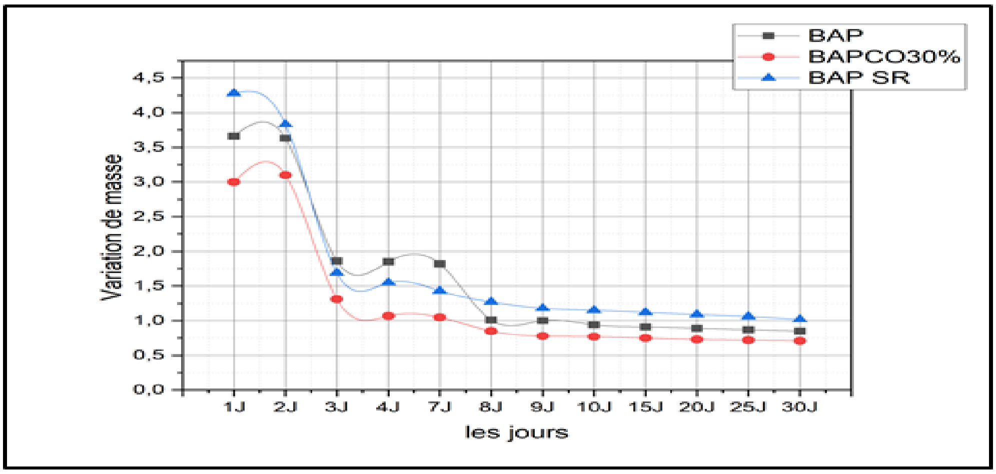
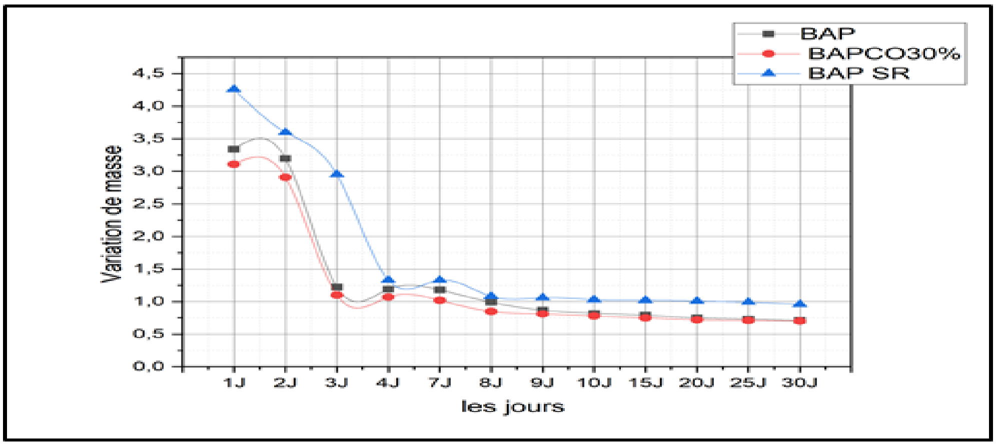


Figure 13: Density values for studied composites

Periodically, the variation in mass of the mixtures studied submerged in the saline solution is assessed. Figure 14 illustrate this variation over time.



(a)



(b)

Figure 14: Mass variations respectively: a) cubic specimens, b) prismatic specimens

The density is slightly lower when 60% eggshell particles are used compared to the standard SCC, but it is higher when using the SCC SR due to the porous nature of this material. The influence of the fibers' density is what accounts for the fact that adding steel fibers increased the mixes' density.

4. Conclusion

In a world where raw materials are scarce, considering waste as a source to be exploited and not as rubbish to be disposed of has become a necessity.

The construction and public works sector produces very large quantities of waste, which is still too often thrown away in places outside urban areas. The recovery of this waste is becoming a major environmental issue.

In this study, it was interested in the recycling of concrete waste by using it as recycled sand, and in the recycling of organic waste presented by eggshells, and the possibility of using them as fine additions in the SCC. The analysis of the results made it possible to draw the following conclusions:

The spread measured for the different series of SCCs and BAPFs complies with the spread criterion, according to the AFGC standard, which qualifies them as self-compacting.The introduction of recycled sand in the composition of SCCs has led to an improvement in its workability,

It was retained an increase in the workability of the SCCs proportional to the increase in the rate of fines substituted by the crushed eggshells.A decrease in workability is observed by adding the hooked steel fibers for all the mixtures studied.

A decrease in the compressive strength was observed for all the SCC mixtures studied by comparing it to that of the reference SCC.The result of the tensile strength obtained for the SCC SR is similar to that obtained by the reference SCC.The tensile strength has been significantly increased with the substitution of limestone filler of 30% eggshell.Increasing this substitution to 60% negatively influenced the tensile strength in SCC CO60%,A positive effect of the addition of fibers was distinguished on the tensile strength of the mixtures studied,The use of 30% recycled sand in the SCC led to a decrease in the water absorption capacity.The addition of fibers to the mixture of SCC with recycled sand (BAPF SR) did not contribute to an additional effect on its water absorption capacity.There has been a noticeable increase in water absorption with time for all examined mixes of SCCs.BAPCO 30% showed better porosity, water absorption capacity, and better durability in an aggressive environment.The increase in fines of substituted eggshells in SCC has led to degradation in the characteristics and durability of the composite.The addition of hooked steel fibers negatively influenced the porous structure of the mixtures studied; an increase in porosity was recorded for all the SFSCCs.

The assessment of the work carried out has highlighted points that can be developed later:

- Additional and more in-depth studies on the effect of crushed eggshell waste and recycled sand on the fresh and hardened cha
- racteristics of SCCs.
- Study the mechanical properties of SCC structures under different types of solicitation, prepared with different volumes of eggshells, and recycled sand.
- Study of the durability of SCCs made with these different wastes in other types of aggressive environments.
- Study the behavior of SCCs made with these different wastes with respect to freeze-thaw.

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Author Contribution

For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, methodology S. CHAIB and R. BENSALEM.; validation, S.CHAIB.; investigation, S.CHAIB.; resources, S.CHAIB.; writing—original draft preparation, S.CHAIB.; writing—review and editing, S. CHAIB.; funding acquisition, S.CHAIB and R. BENSALEM. All authors have read and agreed to the published version of the manuscript."

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of Interest

The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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