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The Effect of the Use of Residues (Metallic Shavings) in the Formulation of Self-Compacting Concrete in Fresh and Hardened State

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ABSTRACT

Self-Compacting Concretes (SCCs) have brought promising insight into the concrete industry to generate environmental impact and reduce costs. the absence of SCC vibrations generates a significant reduction in noise pollution in urban areas, ease of implementation, possibility of concreting heavily reinforced areas or areas with complex geometry and obtaining better quality concrete on the one hand, reduction of working time on site, of personnel during installation and reduction of the costs of industrial processes, on the other hand. Metal chips resulting from the modification of metal parts obtained by turning present problems of environmental pollution and storage. The recycling of this waste in the construction industry is an adequate solution for the production of concrete and can improve some of its properties. An experimental study to study the properties of SCC containing metal shavings with the study of the properties of SCC in the fresh state: flow, L-box and sieve stability. Properties in the hardened state of concretes: compressive strength and ultrasonic pulse velocity. The metal waste in the form of shavings, incorporated in a dosage of 0.5% of concrete volume in the mixtures of SCCs produced, which makes it possible to evaluate the effect of the addition of metal shavings on the characteristics of SCCs in the state fresh and hardened and to recover metal waste, the results confirm the advantage of adding metal shavings in the fresh state the SCCs studied keep their characteristics of self-plasticity, in the hardened state the results show an improvement in the compressive strength of the SCCs studied.

1. INTRODUCTION

SCC is characterized by high fluidity and high spread ability with stability and also ensures good mechanical performance. These concretes were finalized initially by researchers of the university of Tokyo the early 1980s [1]. The concrete goes more and more towards the use of Self compacting. The SCCs are very fluid, homogeneous and with higher stability, they are implemented without vibration. This establishes a great advantage for the realization of the constructions, and this advantage can be observed by the difference between Self-Compacting Concrete and Ordinary Concrete presented in Table 1. The SCC allows to fill complex shape frameworks; where the density in steel reinforcement is very important. In this purpose, the SCC should have well defined properties at the fresh state to know the fluidity degree (flow table test), the filling capacity (box in L) and the resistance in the segregation (stability in the sieve), to assure the rheological stability, the use of organic additives (super-plastiziers and viscosity agent) and mineral additions turns out to be necessary. Rolled and crushed aggregates can be used for the composition of SCC provided that they comply with the EN 12620 standard and that they meet the durability requirements imposed by the EN 206-1 standard. In order to limit the risk of blockage, the maximum diameter of the aggregates must therefore be reduced compared to that of traditional concrete. According to the AFGC [2], the maximum diameter of gravel is between 10 and 20 mm. The gravel increases the granular compactness of the skeleton, which makes it possible to limit the quantity of binder necessary to obtain the desired rheological and mechanical characteristics and on this basis, the AFGC recommends using a gravel/sand (G/S) ratio of l order of 1. In an analysis of the main works concerning the formulation, carried out on more than 68 concretes used for 51 industrial applications, Domone [3] showed that the gravel used is generally crushed and that their maximum diameter does not exceed hardly 20 mm. To facilitate the flow of the mixture, the preparation of good self-compacting concrete generally uses rolled aggregates from rivers and a greater contribution of fines (for example limestone fillers). The risk of blockage in a heavily ironed environment increases when the D max increases. Thus, the D max of the aggregates must be between 10 and 20 mm [4]. Nevertheless, the research on the understanding of the rheological behavior for SCC always remain relevant importance [5].

Due to the increase in building and public works activities over the past few decades, there has been a growing influx of waste from construction sites; industry has a major share of responsibility in the overall pollution of countries, particularly the petrochemical, chemical, metallurgical and mineral processing industries. The recovery of waste in the field of civil engineering is very important because the quality of the materials to be obtained does not require many precautions. Waste can be injected directly into several areas, including the construction sector, which is increasingly interested in waste recovery [6]. The expansion and development of industrial zones experienced by Algeria, especially with the advent of the free market, have generated a large amount of industrial waste. However, the use and recovery of this industrial waste are currently experiencing an undeniable renewed interest in the development of building materials [7]. The objective of this experimental study is to evaluate the rheological and mechanical properties of a self-compacting concrete formulated and reinforced by metal shavings as recovery of metal waste and to see the influence of these shavings on the properties of self-compacting concrete at the fresh state and hardened state. The reuse of metal waste in the manufacture of self-compacting concrete makes it possible to eliminate waste by recycling, hence protecting the environment.

Table 1. Difference between self-compacting concrete and normal cement concrete [8]

Self-Compacting Concrete	ordinary concrete
Concrete has high flowability to undergo compaction by its own weight	Concrete is compacted by external means of vibration
High workability	Less workable mix
Workability gained through superplasticizers and viscosity modifying agents	Workability gained through increased moisture content
Addition of superplasticizer increase the bond between aggregate and cement matrix	The aggregate-cement matrix is weak
Water Content is Low	High Water Content
Fines Content – Cement and Fine aggregate is high	The fines content is less compared to SCC
Lower water content decreases the Bleeding	Bleeding is high
Increased fines content gives a homogeneous mix with less segregation issues	Segregation is higher
Low Viscosity due to high fines content	High Viscosity
SCC structures give good aesthetic finish	Aesthetic finish is not satisfactory
Good choice for thick reinforcement works	Normal concrete are limited in thick reinforcement areas due to external compaction difficulties.

2. EXPERIMENTAL PROGRAMMES

2.1 Materials

The used Cement is a CEM II/B 42.5 delivered from the Lafarge cement plant region of M'sila, having a density of 3.1. Aggregates, the originally siliceous sand resulting from OUED MAITER in the region of Boussaâda wilaya of M'Sila was used. Two fractions of limestone crushed gravel (3/8,8/16) from COSIDER quarry from local region of Bordj Bou Arreridj were utilized. Marble fillers powder of fraction 0,08 mm having a density of 2.67 was kept at variable dosages for the experimental program. The properties of the different materials are presented in Table 1, Table 2, Table 3, Table 4, Table 5 and Figure 1.

The super-plastizier MEDAPLAST SP40 delivered by a local manufacturer GRANITEX and the mixing water from the laboratory of civil engineering for concrete mixtures formulation were used [9-11].

Table 2. The chemical composition of cement (%)

Constituents	Clinker	Marble powder
SiO_2	27.77	0.48
Al_2O_3	7.00	0.10
Fe_2O_3	2.29	0.12
CaO	56.91	54.54
MgO	3.38	0.72
SO_3	2.30	0 .46
Na_2O	0.12	0.079
K_2O	0.51	0.053
L.O.I	2.73	43.55

Table 3. The mineralogical composition of clinker (%)

Constituents	C_3S	C_2S	C_3A	C_4AF
(%)	58 - 64	12 - 18	6 – 8	10 - 12

Table 4. The mineralogical composition of marble powder (%)

Constituents	%
Calcite	98.55
Dolomite	0.14
Quartz	0.12
Illite	0.11
Chlorite	0.39
Kaolinite	0.68
CO2-XRD	43.4

Table 5. Chemical properties of the water

The measure	Content (mg/l)
Temperature degree	24.7
PH	7.78
Conductivity	1799
Chlorine Cl-	234.3
Sulphate So-4	351.6
Water oxidation re-eligibility	1024
magnesium Mg2+	110.8
Sodium Na+	/
Calcium Ca2+	267.2
Dry sediment	1412

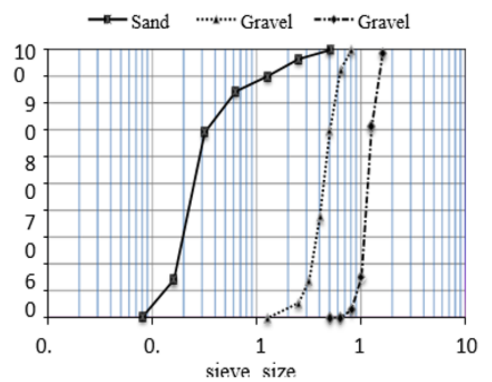

Figure 1. Sieve analysis curve for gravel and sand used

Water is an essential constituent in concrete mixtures because it plays a very important role and takes part in various chemical reactions with cement. Therefore, the quantity and quality of water used must be taken into account more carefully and more seriously because this can certainly help to improve the compressive strength of the formulated concrete. It should be indicated that local potable tap water does not contain any harmful products, and was therefore employed for concrete mixing all through this work. The chemical analysis of the water used was carried out in the chemistry laboratory are shown in Table 5.

2.2 Metallic shavings

The Metal Chips these are spiral mineral fibers, and they come in the form of a spring, their length varies from 1 cm to 5 cm resulting from the modification of metal parts obtained by turning.

Figure 2. Metallic shavings

2.3 Composition of SCC mixtures

For mix design the classical composition for has not been adopted for this program.

The necessary conditions allowing to guarantee the self-compacting and easy placing while based on compositions proposed in the specialized literature were respected in the due formulation of SCC mixtures [12].

It is a question of a choice for the proportioning of constituents in one cubic meter (1 m^3) of concrete by having the following parameters, a proportional of gravel to sand relationship of G/S equal to one (G/S= 1) and a water cement W/C ratio of 0.5.

A defined dosage for the additions such as the superplastizier (2 % of the weight of cement) and a percentage 10% of marble fillers were maintained for this program.

SCC mixture constituents proportion (by cubic meter) is detailed in the Table 6.

Table 6. SCC mixture constituents proportion (by cubic meter)

Constituants	SCC Mix (Kg/m^3)
Sand	830
Gravel 3/8	420
Gravel 8/15	423
Cement	420
Water	210
Super plastizier	8.6
Filler (marbre)	42

Table 7. Composition for types of SCCs mixtures studied

Mix	Fiber Type	Dosage(%)
Cc	Reference (without shavings)	--
CSM	Metallic shavings	0.5

Notes: Cc: Witness Self-Compacting Concrete; CSM: Self-Compacting Concrete with 0.5% Metallic Chips from 1 to 5 cm in length.

To be able to compare the performances of various concretes independently of the cement factor, we fixed the dosage of the latter at 420 kg / m^3. For metal waste, a proportion of 0.5% of the concrete volume was used. A total of two mixtures beside a control concrete mix (0% shavings) for shavings reinforced SCCs were prepared. The mixtures compositions are detailed in the following Table 7.

2.4 Mixing and specimen preparation

The preparation of the SCC mixes asks for more attention and precision. To succeed this task of formulation several trial preliminary tests on the fresh concrete, following the same stages of preparation of an ordinary concrete were made. The rheology tests were performed immediately after the mixing on the fresh concrete; they are realized at least twice to validate the obtained values. Fiber reinforced SCCs mixes followed the same stages of preparation, then the amount of incorporated shavings was added in rains with continuous mixing for around 4 minutes.

A total of 21 cubic (10x10x10) cm^3 specimens for the compression test sand the same number of prismatic ones (7x7x28) cm^3 for flexural essays at sets of three for each test was prepared.

3. RESULTS AND DISCUSSION

3.1 Properties of steel shavings reinforced SCC's and control (Fresh state)

Table 8. Rheological properties of SCC

Concrete type	Rheological properties			
	Flow table test (mm)	L-box (H_2/H_1)	Segregation index (%)	MV
Cc	650	0,84	12,14	2276
CSM	630	0,82	12,34	2893

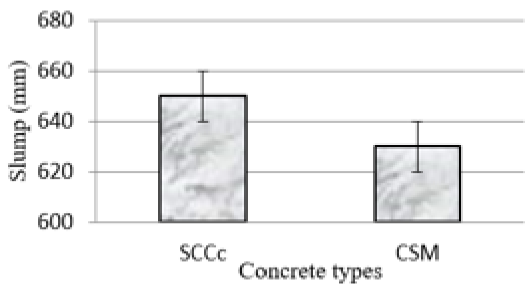

Figure 3. Flow table test results for the different concrete types

The use of metal shavings is like the use of fibers is well known to affect the workability and flowability of plan concrete intrinsically. However, many researchers tried to overcome this problem by using the most workable concrete would be achieved using the optimum aggregate proportions and especially by fixing the optimum content of sand to achieve the best workability as well as, the adding of superplasticizer which can give the concrete high flowability and workability without segregation [13-16]. And when adding mineral fibers or metal shavings, the influence of the type of mineral, the dimensions of the fibers, its shape, and its concentration must be taken into consideration [17]. It can be noticed from Figure 3 noticed a slight reduction of the spreading value of shavings reinforced SCCs compared to the control concrete mix. This can be explained by the lack of workability caused by the effects of frictions between shavings and the matrix of the concrete, this leads (drives) to a decrease of handiness; further to their sticky mix motion provoking slow spreading of concrete material.

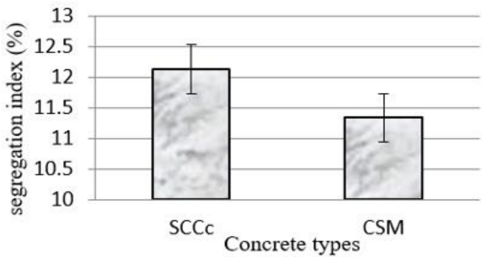

Figure 4. Segregation index test for the different concrete types

The results obtained by the stability sieve test, mark an improvement of the stability with the incorporation of the metallic shavings. The good adhesion between the paste and the shavings explains this advantageous behavior.

This result demonstrates the shavings resulting in an increase the adhesion between shavings and paste. The value registered for shavings reinforced SCC mixture is lower compared to control mix (less than 8).

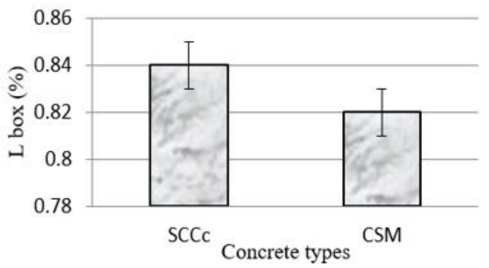

Figure 5. L-box test results for the different concrete types

The L-box test which verifies the ability of a concrete to pass through a densified reinforced zone. It appears clearly from the results obtained on box-L that the greatest value recorded is at the level of the composition of the control concrete without chips and it decreases with the incorporation of chips. The two mixtures also give acceptable filling capacity results and fit well with the recommendations described for self-compacting concretes, that it must be equal to or greater than 0.8 (AFGC 2008) [2].

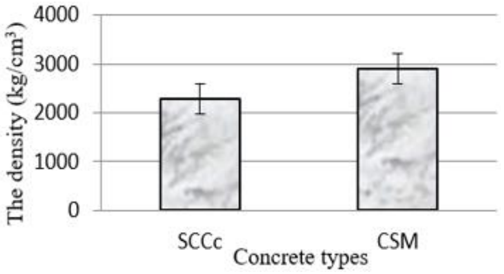

Figure 6. The density for the different concrete types

It is noted from the results obtained that the density of CSM greater than the density of SCCc. This is due to the large mass of metal shavings.

3.2 Mechanical properties of steel shavings reinforced SCC's and control (Hardened state)

The mechanical response to compression is one of the characteristics the mostly studied, likely because it throws generally a global image of the quality of the concrete, because it is directly bound to the structure of the hydrated paste of cement.

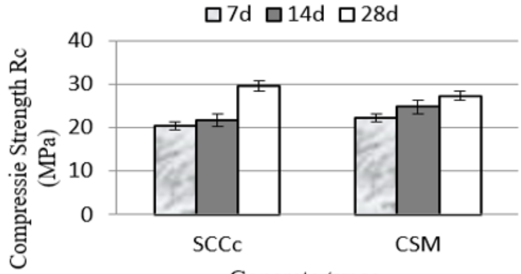

Figure 7. The compressive strength (Rc) for the different concrete types at 7, 14 and 28 days age

According to the results, we notice that the two concrete mixtures studied underwent a regular improvement of the compressive strength with age. It can be noted that the SCCs with metal shavings are significantly more resistant than those without shavings at a young age (7 and 14 days), this difference attributed to the mechanical properties of the shavings. The metal shavings ensure a delay in the appearance of the first crack and efficiency in limiting the propagation through the concrete matrix, thanks to their good adhesion. While the CSM showed a slight degradation of its resistance at 28days compared to the control SCC. This can be attributed to the loss of its mechanical properties over time, as it is just reusable waste.

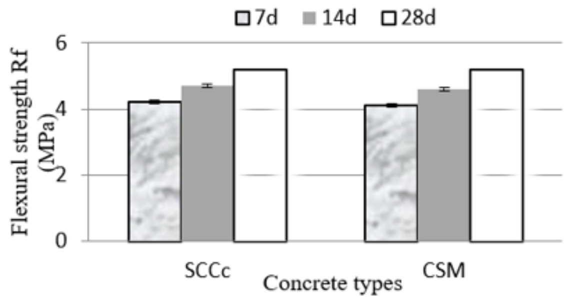

Figure 8. The tensile strength for the different concrete types at 7, 14 and 28 days

According to the results obtained the use of the metal shavings and thanks to their good adhesion improves the flexural strength of the SCC with wire thin metal shavings [14].

The ultrasonic pulse velocity testing method was also applied to check the homogeneity and quality of concrete. This technique uses the propagation of high-frequency sound waves through concrete in which the speed of ultrasonic waves depends on the density of the material [15].

The ultrasonic pulse velocities UPV increases with the age of the concrete, and the addition of metal shavings does not influence the results of ultrasound, the results are in agreement with the results of the compressive strength.

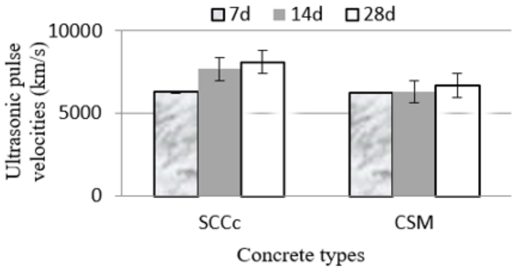

Figure 9. Ultrasonic pulse velocities UPV for different types of concretea types at 7, 14 and 28 days

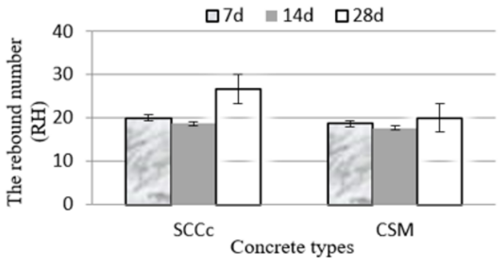

Figure 10. The rebound number (RH) for the different concrete types at 7, 14 and 28 days

The rebound number (RH) increases with the age of the concrete, and the addition of metal shavings does not influence the rebound number (RH) results, the results are in agreement with those of the compressive strength.

4. CONCLUSIONS

The objective of this experimental study is to evaluate the rheological and mechanical properties of a self-compacting concrete formulated and reinforced by metal shavings as recovery of metal waste and to see the influence of these shavings on the properties of self-compacting concrete at the fresh state and hardened state.

According to the obtained results, it can be noticed that

- The spread values are usually fixed between 60 and 75 cm. The two SCCs (SCCc and CSM) present its spreading values comprised between these two values.
- The SCM exhibits a lower spreading value than the spreading value of BAPT. We note from the results obtained that BAP is confined between: $0 \leq \Pi \leq 15$ ie the self-compacting concretes (SCCc and SCM) have satisfactory stability.
- The filling rate must in principle be greater than 0.8 all our SCCs meet this condition.
- It is noted from the results obtained that the density of SCM greater than the density of SCCc. This is due to the large mass of metal shavings.
- We compare these results with those of S. Mostefai [17] we find that SCC with the addition of metal shavings gives the same behavior in the fresh state as SCC with the addition of metal fibers.
- The compressive strength increases with the age of concrete. At 7 days it is the SCM which gives the greatest resistance, the effect of the chips is visible from the first days. The presence of metal shavings affects adhesion, which affects strength.
- The bending tensile strength increases with the age of the SCC and the greatest resistance is given by the SCCc.
- Metal shavings do not significantly increase tensile strength. And we note that they provide the material with a level of ductility and allow better control of cracking.
- The speed of sound increases with the age of the concrete, and the addition of metal shavings does not influence the results of ultrasound, the results are in agreement with the results of the compressive strength.

The sclerometric index increases with the age of the concrete, and the addition of metal chips does not influence the sclerometric index results, the results are in agreement with that of the compressive strength.

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NOMENCLATURE

CEM II/B	Portland cement type
UPV	ultrasonic pulse velocity
RH	rebound hammer
W/C	Water Cement Ratio
Rc	compressive strength