The Eurasia Proceedings of Science, Technology,
Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2024

Volume 32, Pages 1-11

IConTES 2024: International Conference on Technology, Engineering and Science

Fresh and Hardened Properties of Self-Compacting Concrete Reinforced with Recycled Steel Fibers from Mechanical Parts Turning Waste

Sabria Malika Mansour
M'Hamed Bougara University of Boumerdes

Youcef Ghernouti
M'Hamed Bougara University of Boumerdes

Bahia Rabehi
M'Hamed Bougara University of Boumerdes

Abstract: The main reason for using fibers is to control cracking of concrete members due to plastic shrinkage and drying of concrete and to delay crack propagation. The use of fibers such as steel fibers improves the flexural strength and ductility of concrete. The main objective of this work is to study the effects of adding fibers resulting from the turning operation of mechanical parts on the behavior of self-compacting concrete. Fresh properties such as slump flow, passing ability and segregation rate and hardened properties such as compressive strength and flexural strength were analyzed. The obtained results have shown that all produced self-compacting concretes are homogeneous, stable and their mobility in confined environment is ensured. Furthermore, incorporation of fibers in the self-compacting concretes allowed to increase its flexural strength, also to have a gain of ductility witch can avoid sudden failure of the specimens. In conclusion, the turning waste can offer a new source of fiber supply and can replace steel fibers.

Keywords: Self-compacting concrete, Turning waste, Steel fibers, Compressive strength, Flexural strength

Introduction

The objective of making concrete more resistant in flexion and tension still attracts the attention of numerous research. The approach most mentioned in the literature to overcome this weakness in tensile behavior consists of the addition of steel fibers in the concrete formulation. The latter play a reinforcing role, which compensates the fragility of concrete by stitching micro cracking and macro cracking. Thus, the fibers have the capacity to control the opening of cracks, acting as energy absorbers (Mansour, 2021; Mansour, 2020; Haddadou et al.2021). The fibers used in the making of concrete are steel fibers. Despite the appreciable improvements obtained in terms of the mechanical behavior of concrete, the incorporation of fibers into concrete remains problematic from the point of view of workability and homogeneous distribution of fibers. To remedy these problems, the association of fibers with self-compacting concrete (SCC) seems promising. The absence of vibration of these materials avoids a heterogeneous distribution of fibers in the matrix (Haddadou et al., 2021).

In this work, recycled steel fibers obtained from waste of the turning operation carried out on mechanical parts were used to reinforce self-compacting concrete. It is demonstrated that utilizing recycled steel fibers RSF for producing High-Performance fiber reinforced concrete has a potential effect in producing some structures with lower price, higher mechanical performance, and more ecological beneficial impact (Mansour, 2021). Using RSF in concrete efficiently reduces the brittle behavior of concrete, and improves the durability of concrete by arresting crack propagation and limiting the crack width of concrete using bridging action (Ahmad et al., 2023; Alabduljabbar et al., 2019; Ali et al., 2020b; Geng et al., 2021). The main objective of this work is to investigate

---

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

the effects of using recycled steel fibers on the behavior of self-compacting concrete. Three self-compacting concrete mixtures SCCs introducing 0%, 0.5%, and 1% RSF content in terms of volume were analyzed in the fresh state to estimate fresh properties such as spreading, L-box passing ability and resistance to segregation. The hardened phase was related to the evaluation of compressive and flexural strength of the developed SCCs in 7, 14 and 28 days of maturing. In addition, to determine in the hardened state the mechanical properties such as compressive strength and flexural strength. The self-compacting concretes are control SCC concrete and two SCC concretes containing 0.5% and 1% of recycled fibers.

Experimental Program

Materials

The SCC concrete mixtures investigated in this study were prepared with Portland cement (PC) CPJ-CEM II/B 42.5 according with NA 442, EN 197-1 and NF P 15-301/94 standard. Its physical-mechanical properties are given in Table 1. A 0/3 natural sand from Oued Souf was used. The coarse aggregates are crushed from natural limestone rock in two granular classes (3/8 and 8/15). The characteristics of aggregates are given in Table 2. As addition, the limestone fillers rich in CaO were used (Table 1). The particle size analysis of aggregates is shown in figure 1 and the chemical composition of cement and limestone fillers is presented in Table 3.

Table 1. Physical-mechanical properties of cement and limestone fillers

Properties	Cement	Limestone fillers
Specific density(g/cm^3)	3.01	2.66
Blaine specific area(cm^2/g^{-1})	3170	4020
Compressive strength(MPa)	48	-
Flexural strength(MPa)	7	-

Table 2. Physical properties of aggregates

Aggregates	S0-3 mm	G3-8 Mm	G8-15 Mm
Absolute density	2.67	2.71	2,70
Water content	2.49	0.6	0.1
Sand equivalent	79	-	-
Fineness modulus	3.9	-	-
Los Angeles coefficient	-	27	26
Micro Deval coefficient	-	17	16
Water Absorption (%)	2.65	0.97	0.14
Porosity (%)	5.59	1.85	0.40

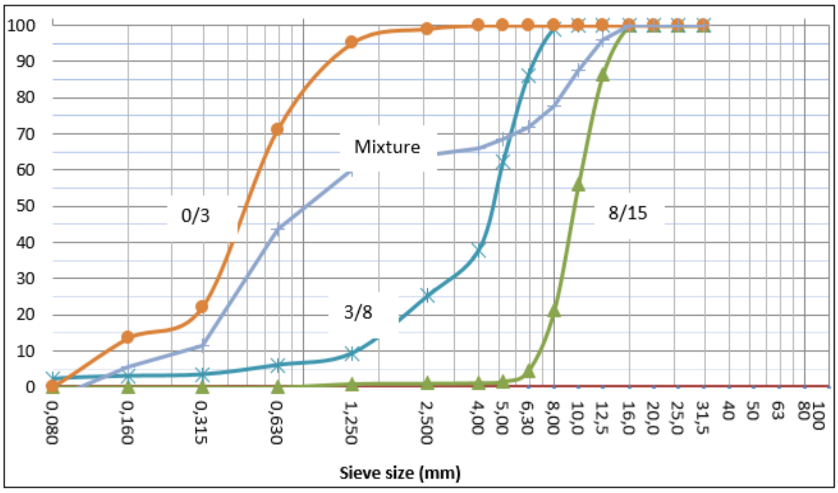

Figure 1. Particle size analysis of aggregates: percentage passing as function as sieve size

Limestone fillers were obtained by extensive grinding of limestone. It is a product with a high limestone content, rich in lime with a CaO content greater than 51%. It is shown that the dominant constituent of Portland cement PC and limestone is CaO.

Table 3. Chemical compositions of cement, limestone fillers

Oxides (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O+ K_2O	LOI	[SiO_2+Al_2O_3+ Fe_2O_3]	Σ
Portland Cement	15.80	4.15	2.31	61.90	2.39	2.80	0.75	9.59	22.26	96.81
Limestone	4.83	1.04	0.37	51.73	0.46	0.08	0.22	41.17	6.24	99.9

The used steel fibers were obtained from waste of the turning operation of mechanical parts. Their technical characteristics are illustrated in Figure 2 and given in Table 4.

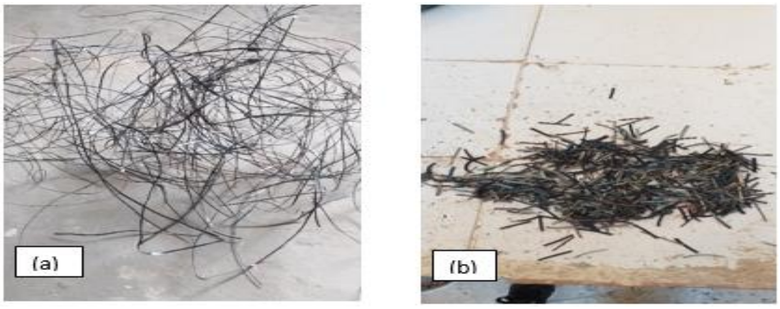

Figure 2. (a) Waste of the turning operation- (b) Waste fibers

Table 4. Technical characteristics of the fibers

Characteristics	Nature	Length	Width	Tensile strength	Young's modulus
Value	Steel	25mm	2mm	227MPa	55678MPa

As superplasticiser (SP), a third generation super water-reducing superplasticizer based on modified polycarboxylates was used at a dosage of 1.7% of cement weight. Its specific gravity is 1.06 and solid content is 25%.

Mix Proportions of Self-Compacting Concretes

Based on the Japanese method (Okamura & Ozawa, 1994), the self-compacting concrete SCC was formulated. Three formulations were elaborated with a water-to binder ratio W/B = 0.38, gravel to sand ratio G/S = 0.9 and a dosage of superplasticizer of 1.7% of cement weight. The dosage of superplasticizer is defined as the admixture saturation point. One (01) reference SCCR concrete without fibers and two (02) SCCs containing 0.5% and 1% of steel fibers respectively were elaborated. The proportions of self-compacting concretes are given in Table 5.

Table 5. Mix proportion of reinforced self-compacting concretes (kg.m-^{3})

SCC/Constituent	SCCR	SCC0.5%	SCC1%
Cement	430	430	430
Limestone Fillers	43	43	43
Sand	924	924	924
Coarse aggregate G3/8	276	276	276
Coarse aggregate G8/15	559	559	559
Water	175	175	175
Superplasticizer	8	8	8
Fibers	-	39	78

Specimen Preparation and Testing

After mixing, the apparent density of fresh SCC concretes was measured according to the standard (NF EN 12350-6, 2012). In addition, workability tests were applied to determine fresh properties, which must be in accordance with Specification and Guidelines for SCC prepared by (EFNARC, 2005, European Federation of National Trade Associations). The tests are Abram cone to determine slump flow diameter according to standard (EN 12350 – 8, 2010), L-box to define the filling rate according to standard (EN 12350 – 10, 2010) as well as sieve stability to characterize the resistance to segregation according to standard (EN 12350–11, 2010).

After, for each SCC concrete, three cubic specimens 150x150x150 mm and three prismatic specimens 70 × 70 × 280 mm were prepared according to European Standard (EN 12390-2, 2012). After 24 h, specimens were cured in water at a temperature of 20 ± 2°C until testing. After 24 h, specimens were cured in water at a temperature of 20 ± 2°C until testing. Finally, destructive tests have been made on cubic specimens to determine compressive strength in accordance with standard (EN, 2012) and on prism specimens to determine flexural strength in accordance with standard (EN 12390-5, 2012) at 7d, 14d and 28 days.

Results

Properties of Fresh SCC Concretes

Bulk Density

Bulk density measurement determines the density performance of the composition of fresh self-compacting concrete and makes it possible to verify the validity of the theoretical formulation. The results are given in Table 6 and illustrated on Figure 3.

Table 6. Workability properties of fresh SCC concretes

SCC/property	Slump flow diameter (cm)	L-Box ratio	Sieve stability (%)	Bulk density (kg.m^{-3})
SSCR	72	0.86	12.4	2341
SCC0.5%	68	0.83	9.2	2338
SCC1%	65	0.81	7.3	2332

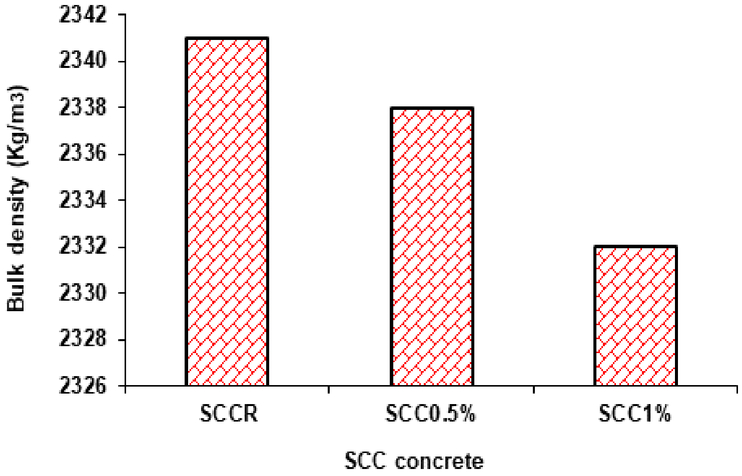

Figure 3. Bulk density of fresh reinforced SCC concretes

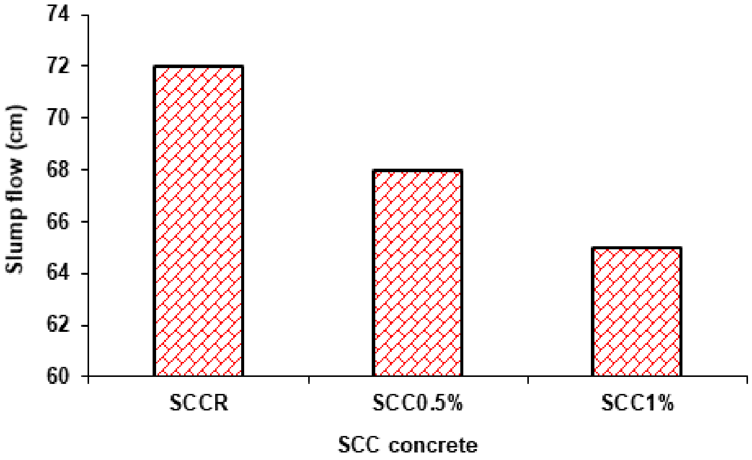

Figure 4. Slump flow diameter of reinforced SCC concretes

Workability Properties

The fluidity and mobility of SCC in an unconfined environment are characterized by measuring the slump flow diameter (Abrams cone) generally fixed in the range 550 cm to 80 cm. Moreover, the mobility of the SCC in confined environment is characterized by the passing rate (H1/H2) (L-Box) which must be greater than 0.8. The sieve stability test allows to assess the risk of segregation must be less than 15% of the global weight. Table 6 shows all results of workability tests on fresh concretes. Results of the tests are illustrated in Figure 4, 5 and Figure 6.

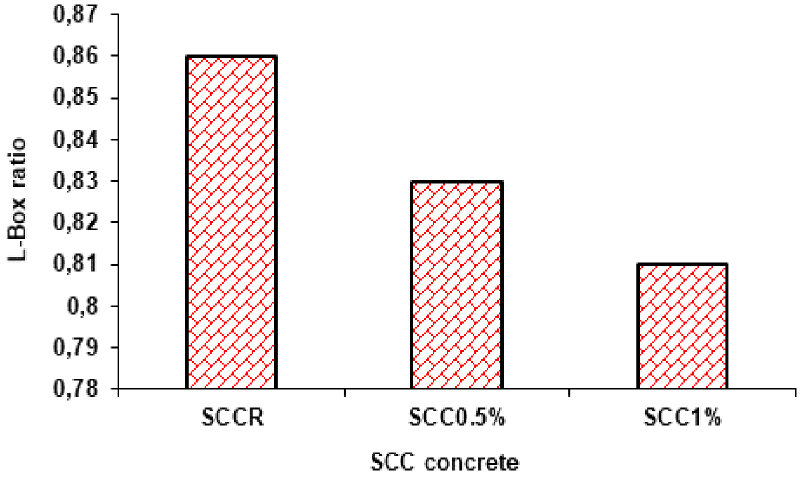

Figure 5. L-Box ratio/ passing ability of SCC Concretes

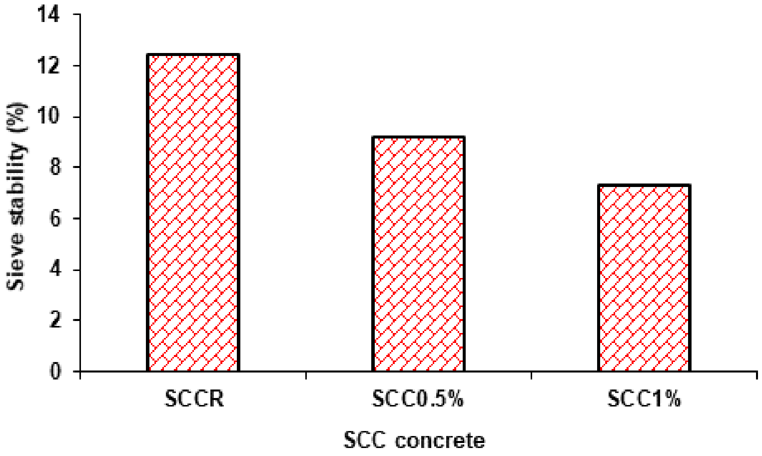

Figure 6. Sieve stability /Segregation rate of SCC concretes

Mechanical Properties of Hardened SCC Concretes

Compressive Strength

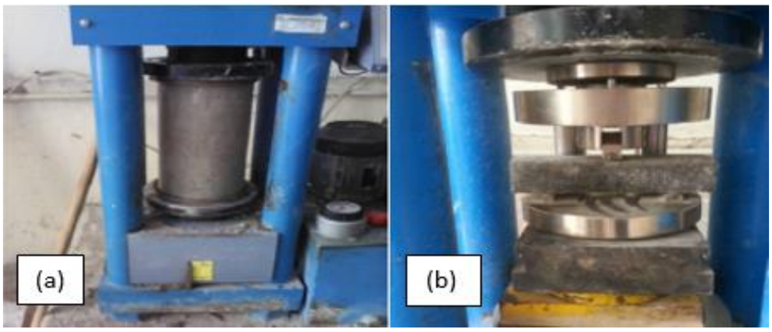

Figure 7. Test on hardened SCCs: (a) - Compression test, (b)- Flexural test

Compressive strength of SCC concretes with and without fibers were determined at 7, 14 and 28 days. The compression tests were carried out with 3000 KN hydraulic compressive testing machine on 150 × 150 × 150 mm^3 cubes. (Figure 7). Results are illustrated in Figure 8 and 9.

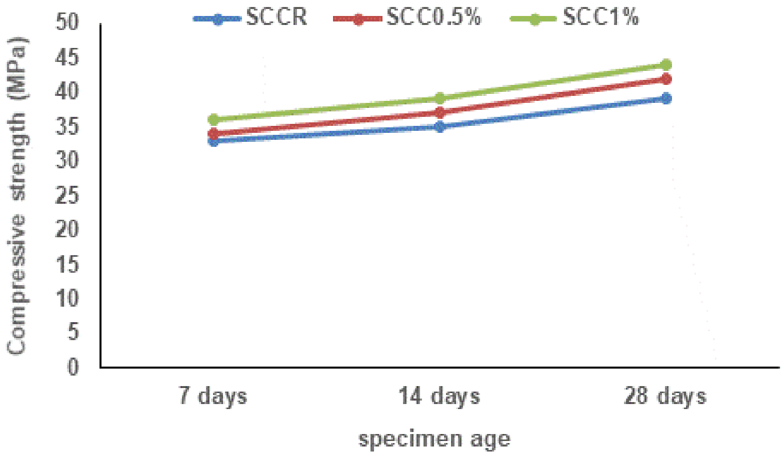

Figure 8. Compressive strength evolution of reinforced SCC concretes as function as age

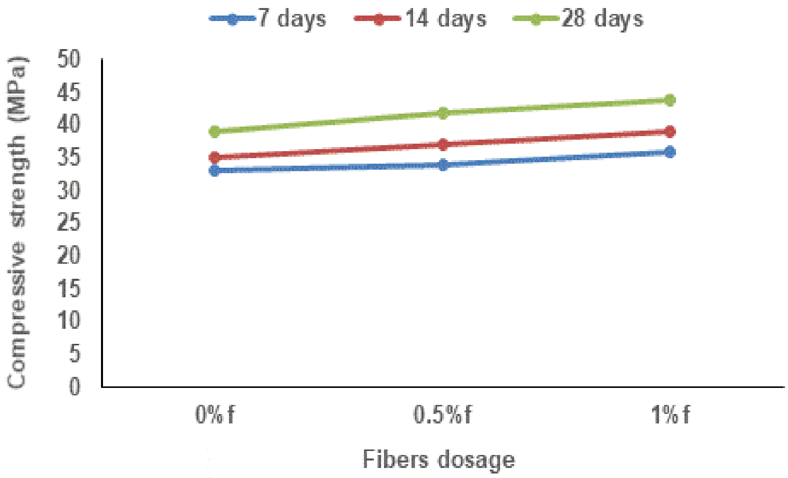

Figure 9. Compressive strength of reinforced SCC concretes as function as fibers dosage

The flexural strength was measured on 70 x70x280 mm^3 prismatic specimens at 7, 14 and 28 days old applying a three-point bending test, (Figure 7). Test results are reported in Figure 10 and 11.

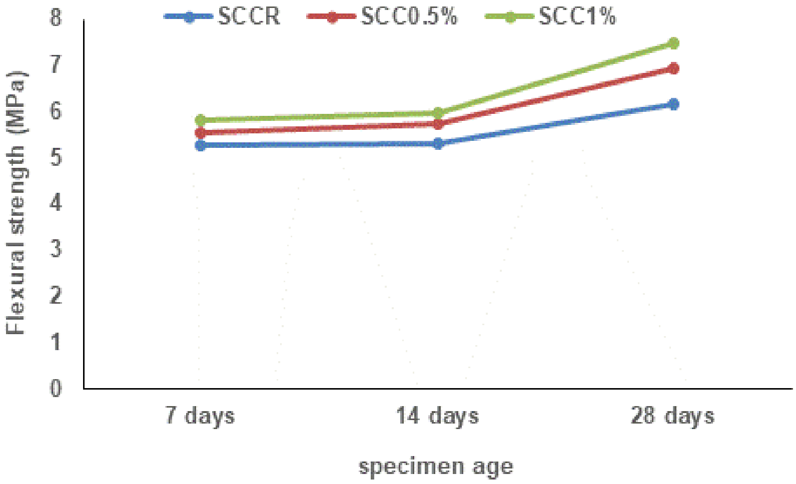

Figure 10. Flexural strength evolution of reinforced SCC concretes as function as age

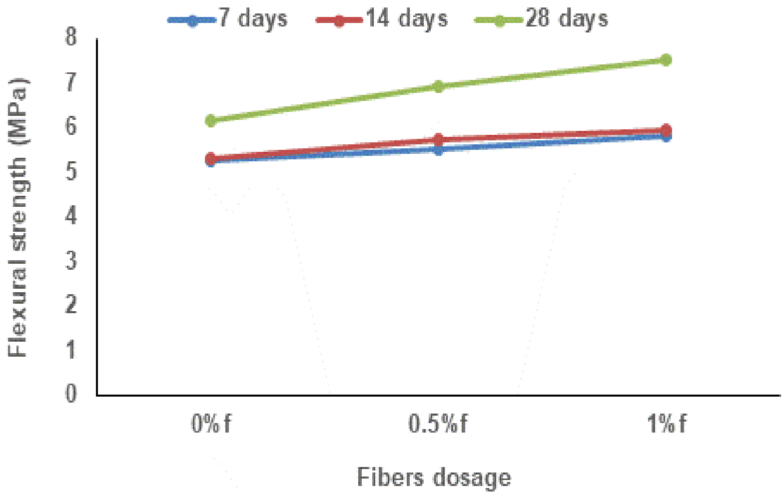

Figure 11. Flexural strength of reinforced SCC concretes as function as fibers dosage

A relationship between compressive strength and its flexural strength at 7, 14 and 28 days was obtained with a correlation coefficient R^2 of 0.9073 for all specimens (Figure 12). The analyses show an excellent linear relationship expressed by equation (1):

$$f_f = 4.7726 \text{ x } f_c + 9.0307 \qquad (1)$$

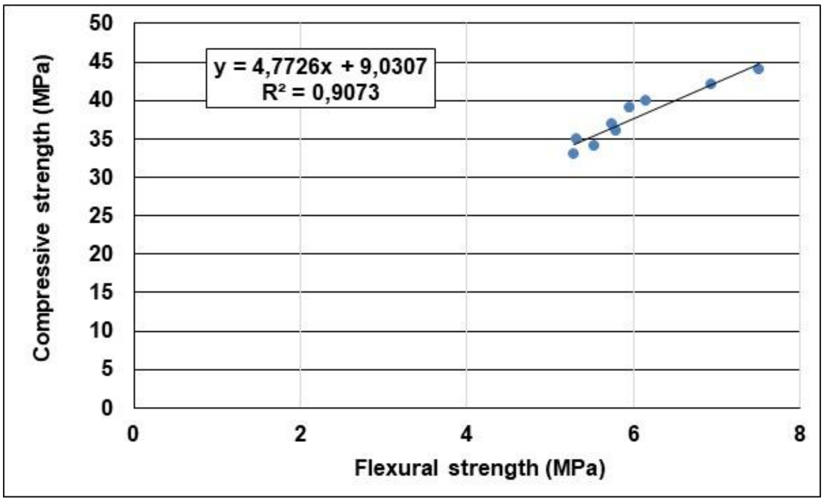

Figure 12. Relationship between flexural and compressive and flexural strength of SCC

Discussion

Properties of Fresh SCC Concretes

Bulk Density

Measurement of fresh bulk density determines the volume yield of the composition of fresh self-compacting concrete and makes it possible to verify the validity of the theoretical formulation. The results illustrated in Figure 3 showed that the bulk density values of the fiber-reinforced SCCs were practically the same compared to that of the control SCC without fibers. This is due to the weight of the fibers, which is considered low compared to the weight of the aggregates.

Workability Properties

To classify a concrete as self-compacting, the requirements for filling and passing ability as well as segregation resistance must follow the limitations specified by EFNARC. Indeed, the obtained results correspond to the criteria of the recommendations of EFNARC. The fresh properties are in the range of 65-72 cm for the slump flow, 0.81- 0.86 for the L-box ratio and 7.3% - 12.4% for the sieve stability. All concrete mixtures are considered as Self- compacting concretes (SCC).

The results of Figure 4 show that all SCC concretes have slump flow values located within the SCC range (60cm- 80cm). The coarse aggregates and fibers were distributed uniformly and no concentration of the latter could appear in the center of concretes. They were homogeneous. Nevertheless, a reduction of the slump flow values of fibered SCCs compared to the control concrete was marked. In addition, increasing the fiber dosage from 0.5% to 1% reduced spreading and therefore reduced flow capacity. This is due to the presence of fibers, which slightly slowed down the movement of SCC during its spreading due to its thickening. The reduction of slump flow is 5.6% for SCC0, 5% and 10% for SCC1%.

The SCC Mixes can be classified as SF1 slump flow class concrete except for SCC containing 1% of fibers, which is classified as SF2. The SF1 class is suitable for unarmed or weakly armed structures or for lining tunnels, piles and certain deep foundations. The SF2 class is suitable for ordinary applications such as walls and columns (Madandoust & Mousavi, 2012).

Moreover, for all SCC concretes, L-Bx ratio (the filling rate) was greater than 0.8 (Figure 5). This avoided the risk of blocking of concretes between the reinforcement and therefore their mobility in a confined environment was ensured. Indeed, results showed that All SCCs mixtures can be classified as PL2 (passing ability ≥ 0.80 with 3 rebars) regarding the NF EN 206-9 consistency classification (Badogiannis et al., 2005). These SCCs mixes are suitable for placing into formwork with more closely spaced and denser reinforcement (Liu, 2009). The greatest value of filling capacity recorded was at the level of the control SCC composition. This decreased slightly with the incorporation of fiber. As the fiber dosage increased from 0.5% to 1%, the filling capacity decreased. This means that the fibers have slightly weakened the flow through more or less dense reinforcement. This reduction is not significant because the fibers used are very short and fine. The reduction of L-Box is 3.5% for SCC0,5% and 6% for SCC1%. The results are consistent with what can be expected from self-compacting concrete. However, the most important in this test is that the tested concrete flows through the reinforcement correctly, which is directly related to workability.

The sieve stability test made it possible to calculate a segregation rate and to deduce whether the tested concrete has satisfactory stability or not. The results (Figure 6) of the sieve stability tests used to measure the ability of self-compacting concrete to resist static segregation show acceptable rates values for all compositions according to the EFNARC recommendations. Indeed, the segregation rates obtained are all less than 15% indicating satisfactory stability for all SCCs according to the acceptability criteria of a formulation of an SCC. None of the SCCs developed presented a risk of static segregation. According to the NF EN 206-9 standard (Afnor & EN, 206-9, 2010), all fiber SCCs mixtures under investigation can be categorized as sieve segregation class 2 (SR2) since all values of the segregation rate are less than 15% of the sample weight. In addition, the rate of fibered SCCs containing fibers did not exceed that of the control SCC. An improvement in stability was marked with the incorporation of fibers. It clearly appears that the high rate value recorded was at the level of the composition of the control SCC. The latter decreased with the incorporation of fiber. The lower the segregation rate, the greater the resistance to segregation, the more stable the SCC. When the fiber dosage increased, the resistance to segregation increased. Fiber SCCs are homogeneous and more stable than reference SCC. The good adhesion between cement paste and fibers explains this advantageous behavior. Compared to the segregation rate of the control SCC, the reduction is 26% for SCC0.5% and 41% for SCC1%.

In conclusion, results of the tests on the SCCs in the fresh state showed that since the slump flow of the tested concretes are greater than 60 cm, their passing rate in the L-box is greater than 80%, the segregation rate is less than 15 %, are stable, homogeneous and present no risk of segregation according to EFNARC criteria. It seems that 0.5% of fibers is the optimum rate for good fresh properties of SCC.

Properties of Hardened SCC Concretes

Compressive Strength

Figure 8 shows the evolution of compressive strength of SCCs with age. It is clearly shown that the compressive strength of all SCCs increased with age from 7d, 14d to 28d. Compared to the 7-day strength, the increase is 6%

at 14 days and 12% at 28 days for control SCC. It is 9% at 14 days and 15% at 28 days for SCC0.5%. It is 8% at 14 days and 14% at 28 days for SCC1%. Figure 9 shows that the compressive strengths of the fibered SCCs (SSC0.5% and SCC1%) exceed that of the control SCCR at all maturities. Indeed, compared to SCCR control, a slight increase of compressive strength was obtained. It is of the order of 3% and 9% at 7 days, 5% and 11% at 14 days and 28 days for SSC0.5% and SCC1% concretes respectively. The best formulation of fibered SCC concrete is that containing 1% of fibers from mechanical parts turning waste.

Flexural Strength

The results of the bending tests carried out on the different SCCs at 7, 14 and 28 days are ullustrated in Figure 10 and 11. It is clearly shown in Figure 10 that the strengths of all SCCs increased according to the age. Compared to the 7-day strength, the increase is 0.8% at 14 days and 16% at 28 days for control SCC. It is 4% at 14 days and 25% at 28 days for SCC0.5%. It is 3% at 14 days and 29% at 28 days for SCC1%. Moreover, Figure 11 shows the effect of fibers on the flexural strength. Indeed, the flexural strengths of the SCCs containing the fibers exceed those of the control SCCR without fibers at all ages. In addition, as the fiber dosage increases, the strength increases. SCC1% fibered with 1% presents a strength greater than that of SCC0.5% fibered with 0.5% as well as that the control SCCR. Compared to the SCCR strength, a gain of around 5% and 10% at 7 days, 8% and 12% at 14 days, 13% and 22% at 28 days was obtained for SCC0.5% and SCC1% respectively. The higher gain is that of SCC containing 1% filming waste fibers. This increase in flexural strength is attributed to the good adhesion between the fibers and the cement matrix as well as the strength of the used fibers. A relationship between compressive and flexural strength was obtained with a correlation coefficient R^2 for all specimens of 0.9073 (Figure 7). Analyses show a good linear relationship expressed by equation (1):

$$f_c = 4.7726 x f_f^{\,2} + 9.0307 \qquad (1)$$

Breaking Mode

Case of Control SCCR Concrete

According to Figure 12, the failure of the control SCC concrete is considered fragile, when the strength limit is reached, we observed a sudden rupture of the specimen which breaks and divides into two parts, this is explained by the low strength of SCCR alone to the tensile forces developed in the tense zone of the flexed element.

Figure12. Fragile failure at mid-span of the control SCCR specimen

Case of Fiberized SCC

The mode of failure observed on the fiber-reinforced concrete specimens is different to that of the control SCC (Figure 13). There are appearance of micro cracks and a major crack in the body of the SCC without it dividing into two parts. This is the ductile failure mode due to the presence of fibers, whose role is to sew the micro cracks and stop the rapid development of the opening of the master crack. Finally, we can say that the fibers work to increase the flexural strength and their presence is a barrier, which counteracts and resists external pressures.

Figure 13. Fragile failure at mid-span of fiberized SCC specimen

Conclusion

According to the results obtained in this work on using recycled steel fibers obtained from waste of the turning operation in SCCs self-compacting concretes, the following conclusions could be drawn:

- The Japanese method made it possible to provide a better SCC concrete composition whose properties in the fresh and hardened state are satisfactory.
- From a workability point of view, results of the tests on all concretes with and without fibers showed that the fresh properties are in the range of 65-72 cm for the slump flow, 0.81- 0.86 greater than 80% for the passing ability in L-box and 7.3% - 12.4% less than 15 % for the segregation rate from sieve stability. All concrete mixtures were considered as Self- compacting concretes (SCCs). These concretes are stable, homogeneous and present no risk of segregation according to EFNARC criteria. It seems that 0.5% of fibers is the optimum rate for good fresh properties of SCC.
- The incorporation of fibers into the SCC made it possible to increase its compressive strength by a maximum of 14% at 28 days and its flexural strength by 22% with 1% fibers. The latter made it possible to gain plasticity, delay cracking, reduce the width of the cracks and avoid sudden rupture of the specimens.
- Good linear relationship was obtained between the compressive strength and flexural strength with a correlation coefficient R^2 of 0.9073 for all specimens.
- Concerning breaking mode, the failure of the control SCC concrete is considered fragile, when the strength limit is reached, we observed a sudden rupture of the specimen, which breaks and divides into two parts. The mode of failure observed on the fiber-reinforced concrete specimens is different to that of the control SCC. There are appearance of micro cracks and a major crack in the body of the SCC without it dividing into two parts. This is the ductile failure mode due to the presence of fibers, whose role is to sew the micro cracks and stop the rapid development of the opening of the master crack.
- The possibility of using recycled steel fibers obtained from waste of the turning operation in self-compacting concretes SCCs allow to contribute in a fairly humble way to the valorization of the latter at low cost, to the national economy and can also mitigate environmental problems. In conclusion, the turning waste offers a new source of fiber supply and can replace steel fibers.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the authors.

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Technology, Engineering and Science (www.icontes.net) held in Antalya/Turkey on November 14-17, 2024.

References

Afnor. (Ed.). (2010.) *NF EN 206-9 : Béton – partie 9 : Règles complémentaires pour le béton auto – plaçant* (p.28). Paris, France : Afnor.

Ahmad, J., Zhou, Z., & Deifalla, A. F. (2023). Steel fiber reinforced self-compacting concrete: A comprehensive review. *International Journal of Concrete Structures and Materials*, *17*(1), 51.

Alabduljabbar, H., Alyousef, R., Alrshoudi, F., Alaskar, A., & Fathi, A., & Mohamed, A. M. (2019). Mechanical effect of steel fiber on the cement replacement materials of self-compacting concrete. *Fibers*, *7*(4), 36.

Ali, I. F., Abdulridha, A. A., & Abbas, S. A. (2020b). Behavior and strength properties of steel fiber reinforced self-compacting concrete columns. *Journal of Engineering Science and Technology*, *15*(5), 3204–3217.

Badogiannis, E., Kakali, G., Dimopoulou, G., Chaniotakis, E., & Tsivilisa, S. (2005). Metakaolin as a main cement constituent. Exploitation of poor Greek kaolins. *Cement and Concrete Composites*, *27*(2), 197–203.

EFNARC. (2005). *European guidelines for self-compacting concrete: specification, production and use, self-compacting concrete.* Retrieved from https://www.theconcreteinitiative.eu.pdf

Geng, H., Ding, X., Hao, Du., Shi, J., Li, C., & Li, X. (2022). Application of self-compacting steel fiber reinforced concrete for pervious frames used for river revetment. *Applied Sciences*, *12(*20), 10457.

Haddadou, N., Boulkhiout, M., Mansour, S.M., Chaid, R., & Ghernouti, Y. (2021). The effect of steel fiber size on the properties of fresh and hardened self-compacting concrete incorporating marble powder. *SSP Journal*, 16(1), 23-34.

Liu, M. (2009). *Wider application of additions in self-compacting concrete*. (Doctoral dissertation, University College London, UK).

Madandoust, R., & Mousavi, S.Y. (2012). Fresh and hardened properties of self-compacting concrete containing metakaolin. *Construction and Building Materials*, *35*, 752–760.

Mansour, S. M. (2020). Physical-mechanical properties of steel fiber- reinforced self-compacting concrete containing natural perlite addition. *International Journal of Microstructure and Materials Properties*, *15*(2).

Mansour, S. M. (2021). New generation of fiber self-compacting concrete based on pyrophyllite. *Emerging Materials Research*, *10*(2), 1-12.

Mansour, S. M. (2021). Use of natural pyrophyllite as cement substitution in ultra performance polypropylene fiber concrete. *International Journal of Engineering Research in Africa*, *56*, 123-135.

NF EN 12350-10. (2010). *Essai pour béton frais – partie 10 : Béton autoplaçant – Essai à la boite en L.* Paris, France : Afnor.

NF EN 12350-11. (2010). *Essai pour béton frais – partie 11 : Eton autoplaçant – Essai de stabilité au tamis.* Paris, France: Afnor.

NF EN 12350-6. (2012). *Essais pour béton frais – Partie 6 : Masse volumique*. Paris, France: Afnor.

NF EN 12350-8. (2010). *Essai pour béton frais – Partie 8 : Béton autoplaçant – Essai d'étalement au cône d'Abrams*. Paris, France: Afnor.

NF EN 12390-2. (2012). *Essais pour béton durci – partie 2 : Confection et conservation des éprouvettes pour essais de résistance*. Paris, France: Afnor.

NF EN 12390-3. (2012). *Essais pour béton durci – partie 3 : Résistance à la compression des éprouvettes*. Paris, France: Afnor.

NF EN 12390-5. (2012). *Essais pour béton durci – partie 5 : Résistance à la flexion sur éprouvettes*. Paris, France: Afnor.

Okamura, H., & Ozawa, K. (1994). Self- compacting high performance concrete in Japan. *International Workshop on High Performance Concrete*, 31–44.

Author Information

Sabria Malika Mansour
M'Hamed Bougara University
Avenue de l'Indépendance, 35 000 Boumerdès – Algeria
Contact e-mail: *s.mansour@univ-boumerdes.dz*

Youcef Ghernouti
M'Hamed Bougara University
Avenue de l'Indépendance, 35 000 Boumerdès – Algeria

Bahia Rabehi
M'Hamed Bougara University
Avenue de l'Indépendance, 35 000 Boumerdès – Algeria

To cite this article:

Mansour, S.M., Ghernouti, Y., & Rabehi, B., (2024). Fresh and hardened properties of self-compacting concrete reinforced with recycled steel fibers from mechanical parts turning waste. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 32,* 1-11.