DOI: 10.2478/sspjce-2025-0003

Formulation and characterization of steel fiber reinforced self-compacting concrete (SFRSCC) based on marble powder

Tarek Naadia[1], Djamila Gueciouer[2], Youcef Ghernouti[3]

[1]Laboratory: LBE, Houari Boumediene University (USTHB) / Lecturer at EPAU, Algiers, Algeria
[2]Research Unit: URMPE, M'hamed Bougara University, Boumerdes / Lecturer at EPAU, Algeria
[3]Research Unit: URMPE, M'hamed Bougara University, Boumerdes, Algeria
t.naadia@epau-alger.edu.dz

Abstract:

The main objective of this research is the formulation, and the rheological and mechanical characterization of steel fiber-reinforced self-compacting concrete (SFRSCC) based on an industrial by-product, marble powder. This study aims to develop a fiber-reinforced SCC with optimal rheological and mechanical properties. The rheological results of the SFRSCC indicate that the addition of steel fibers directly affects the workability of the mix, with this influence depending on the fiber dosage. Indeed, the introduction of fibers leads to a noticeable reduction in slump flow, along with an increase in flow time. Simultaneously, the mechanical results show a significant improvement in flexural strength and ductility as the fiber dosage percentage (%f) increases. However, the compressive strength is only slightly affected by the increase in fiber dosage. Moreover, marble powder plays a crucial role in improving the flowability and stability of the SFRSCC. It enhances the mix's compactness by filling the voids between aggregates, which promotes more homogeneous flow and reduces the risk of segregation. This synergy between steel fibers and marble powder optimizes the performance of SCC, making it suitable for various applications in the construction field.

Keywords: steel fibers, marble powder, ductility, workability, flexural strength, compressive strength.

1 Introduction

Self-compacting concrete (SCC) is regarded as a major innovation in construction materials, offering exceptional fluidity and the ability to compact without the need for mechanical vibrators. However, its mechanical performance, particularly in flexural and tensile strength, may be limited.

Jarugumalli [1] demonstrated that the addition of marble powder improves the rheological properties of SCC by up to 40%, increasing the spread diameter and reducing the flow time. However, beyond this percentage, signs of segregation were observed, while a 54% increase in compressive strength and an improvement in flexural strength were noted.
The combined effect of metallic fibers and marble powder on reinforced SCC was studied by Ahmad [2]. Adding steel fibers up to 1.5% significantly improved compressive strength (+24.8%) and tensile strength (+77.2%), while transforming a brittle failure into a ductile one. However, higher dosages reduced the workability of the concrete. Marble powder, used as a partial replacement for sand, enhanced the density and adhesion between the cementitious matrix and the fibers, facilitating the flow of the mix.

The work of M.R. Ch. Rajendra Prasad et al. [3] showed that partially replacing cement with marble powder (up to 20%), combined with 0.2% metallic fibers, significantly improved compressive, tensile, and flexural strengths, especially after 28 days. This combination also reduced cement consumption, offering a high-performance, eco-friendly concrete suitable for demanding structural applications.
Similarly, Ankathi Rajesh [4] found that substituting 15% of cement with marble powder, combined with 2% steel fibers, optimized mechanical performance while maintaining good workability. This combination improved durability while reducing the environmental impacts associated with cement production.

Wani [5] highlighted those metallic fibers influence both the rheological and mechanical properties of SCC. While fibers reduce workability, moderate dosages allow acceptable flow properties to be maintained. Mechanically, fibers increase compressive strength (+16%) and flexural strength due to their crack-bridging effect, while enhancing ductility, which is essential for structures subjected to dynamic loads.
B.C. Xavier [6] demonstrated that mixes containing 30% marble powder and 10 kg/m³ of metallic fibers achieve a specific strength 50% higher than conventional SCC while reducing cement consumption. These formulations stand out for their ecological efficiency and potential for future applications.

Vijaya Kumar [7] also observed that adding metallic fibers reduces workability but significantly improves the mechanical strength of reinforced SCC by delaying crack propagation and increasing ductility. Moreover, incorporating 15% marble powder, as demonstrated by Velci Shridevi [8], enhances compressive and flexural strengths, although workability is slightly reduced.

Haddadou N. et al. [9] studied the impact of various mineral additions and fibers in SCC, with 30% of the cement replaced by marble powder, metakaolin, or limestone powder. Marble powder improved the fluidity of the concrete, while metakaolin optimized compactness and strength. The addition of hybrid fibers (steel-polypropylene) enhanced ductility and flexural and tensile strengths while maintaining self-compacting properties in accordance with EFNARC standards, providing a sustainable solution for structural applications. In another study, Haddadou et al. [10] examined the effect of metallic fibers of various sizes. They showed that short fibers increase compressive strength by limiting microcracks, while long fibers enhance ductility and fracture energy.

Ahmad [11] employed the response surface methodology (RSM) to optimize the addition of marble waste and superplasticizers in mixes reinforced with steel fibers. While the addition of fibers improves mechanical properties up to 1.5%, higher dosages degrade rheological performance.

In another investigation, Ahmad et al. [14] analyzed the partial replacement of cement or aggregates with marble waste (WM) in SCC. Substitution up to 20% improved fluidity, compactness, and segregation resistance without compromising mechanical performance. Beyond 20%, porosity and mechanical performance decreased. This approach offers a sustainable solution by reducing waste and CO_2 emissions while maintaining good performance.

Khaloo [12] observed that increasing steel fibers improves flexural strength but reduces workability and compressive strength. Tabatabaeian [13] showed that using hybrid fibers (steel and polypropylene) reduces workability while improving flexural rigidity.
Gueciouer [15] optimized a steel fiber-reinforced SCC (SFSCC) with marble powder as an addition and partial cement replacement using design of experiments (DOE). The study showed that increasing fiber dosage enhances ductility (up to 377%) but reduces flowability. Paste volume influences strength, while fibers control ductility, validating the use of marble powder as a high-performance, sustainable material.

Finally, Keval [16], Frazão [17], and Paul [18] demonstrated that adding steel fibers significantly improves flexural, tensile, and energy absorption strengths, although excessive fiber content may reduce compressive strength.
The objective of this research is, therefore, to optimize the formulation of SCC reinforced with metallic fibers and marble powder to achieve improved rheological and mechanical properties, meeting the growing demands for durability and performance in the construction sector.

2 Experimental program

Material used

The cement used for all the compositions is a blended Portland cement (CPJ CEM II / B - 42.5). Furthermore, marble powder was used as an addition. The chemical compositions and physical properties of the cement and marble powder are provided in tables 1 and 2, respectively.

Table 1: Chemical compositions of the cement and the marble powder

Components (%)	Cement	Marble
SiO_2	15.71	2.08
Al_2O_3	4.15	0.48
Fe_2O_3	2.52	0.11
CaO	60.7	54.15
MgO	2.39	0.19
K_2O	0.59	0.08
Na_2O	0.18	0.01
SO_3	1.79	0.01
P_2O_5	/	0.02
TiO_2	/	0.01
Cao free	1.42	/
Cl	0.025	/
Ins	2.82	/
F.L	11.6	42.82

Table 2: Physical properties of the cement and the marble powder

Characteristic	Marble	Cement
Bulk specific density (g/cm^3)	0.96	/
Specific weight (g/cm^3)	2.69	2.99
Porosity	0.5	/
Color	White	Grey
Specific surface (SSB) (cm^2/g)	5910	4026
Standardized consistency H_2O (%)	/	26.6
Time of initial setting	/	140min
Time of final setting	/	250min

A natural silica sand (0/4) from Oued Souf and two types of crushed gravel, gravel (3/8 and 8/15), which share the same mineralogy, were used as aggregates. The main characteristics of the aggregates used are provided in table 3.

Table 3: Characteristics of aggregates

Characteristics	Symbol	Sand 0/4	Gravel 3/8	Gravel 8/15
Absolute density (g/cm^3)	P_S	2.67	2.73	2.73
Moisture content (%)	W	0.46	0.2	0
Water absorption (%)	A_s	1.68	0.45	0.30
Micro Deval (%)	$M_{DE}^{(1)}$	/	19.98	14.72
Los Angeles (%)	$L_A^{(2)}$	/	30	41.26
Fineness modulus	M_f	2.56	/	/
Sand equivalent (%)	$ESV^{(3)}$	83	/	/
	$ESP^{(4)}$	81		

(1) Resistance to wear of aggregates in a rotating drum (Micro Deval test), measured according to the NF EN 1097-1 standard.
(2) Abrasion resistance of aggregates (Los Angeles test), measured according to the NF EN 1097-2 standard.
(3) Visual Sand Equivalent, determined by visually measuring the height of clean sand after sedimentation, without using a piston.

(4) Piston Sand Equivalent, determined by measuring the height of clean sand after sedimentation using a piston for greater accuracy.

The superplasticizer used is a high-range water reducer (HRWR), conforming to EN 934-2, based on polycarboxylates and marketed under the name Medaflow 145.
Steel fibers with hooks, referred to as 'Dramix' were used, as shown in figure 1, and theircharacteristics are presented in table 4.

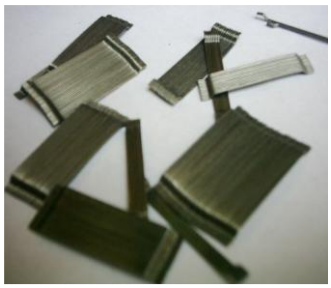

Figure 1: Steel fibers used

Table 4: Standard characteristics of fibers

Shape	Hooks
Bonding	Bonded
Length (mm)	50
Diameter (mm)	0.55
Tensile strength (N/mm^2)	1345
Aspect ratio (L/D)	55
Density	7.8

2.2 Experimental Method

To optimize the rheological and mechanical parameters of steel fiber-reinforced self-compacting concrete (SFRSCC), five (5) compositions of SCC with marble powder were produced and studied. One composition without fibers, considered as the reference (RSCC), and four others with different percentages of metallic fibers (0.2%, 0.3%, 0.4%, and 0.5%) by volume of concrete were prepared. The compositions of these five (5) SCC mixes are provided in Table 5. It should be noted that the reference concrete resulted from a prior optimization of its rheological and mechanical properties. Its optimal paste contains a cement substitution rate with marble powder of 20% (i.e., 80 kg/m³) and an additional 10% of marble powder (i.e., 40 kg/m³). The initial cement dosage is 400 kg/m³, and the specific surface area (Blaine) of the marble powder is 5910 cm²/g.

The mixes of the four (4) steel fiber-reinforced self-compacting concretes (SFRSCC) and their reference self-compacting concrete (RSCC) were subjected to standard rheological tests immediately after mixing, namely: the Abrams cone slump test, the L-box flow test, and the sieve stability test, in accordance with the recommendations of AFGC [19]. For the mechanical tests, the samples were cast and lightly vibrated to ensure a homogeneous surface. The prismatic specimens (7 × 7 × 28 cm) for the flexural tensile strength test, conducted according to the NF P18-407 standard, and cylindrical specimens (⌀16 cm × 32 cm) for the uniaxial compression test, conducted according to the NF P18-406 standard, were demolded after 24 hours and cured in water at 20 ± 2 °C until the age of 28 days. Before the compression test, the cylinder faces were leveled by pouring a layer of liquid sulfur to ensure perfect flatness.

Table 5: Mix designs of the SCC studied (in Kg/m³)

	RSCC	SFRSCC1	SFRSCC2	SFRSCC3	SFRSCC4
Cement	320	320	320	320	320
Marble Powder	120	120	120	120	120
Superplasticizer	6.16	6.16	6.16	6.16	6.16
Water	176	176	176	176	176
Sand (0/4)	940	940	940	940	940
Gravel (3/8)	506	506	506	506	506
Gravel (8/15)	337	337	337	337	337
Fibers	0	15.6	23.4	31.2	39

3 Results and discussions

The conventional rheological tests conducted on the four (04) steel fiber-reinforced self-compacting concretes (SFRSCC), as well as on the control concrete, include the slump flow test using the Abrams cone, the flow time, sieve stability, and the L-box test, as illustrated in figure 2.

a. Abrams cone test b. Sieve stability testc. L-box test

Figure 2: Fresh state tests of the studied self compacting concretes

The results of the rheological parameters of the four (04) fiber reinforced self compacting concretes (SFRSCC) studied, as well as those of the reference concrete, are represented by the histograms in figures 3, 4, 5, and 6, as well as by table 6.

Table 6: Results of the fresh-state tests of the studied self-compacting concretes

Type of SCC	Slump flow (cm)	T500 time (s)	L-box H2/H1	Sieve stability (%)	Bulk density (Kg/m^3)
RSCC	75	2.36	0.93	8.33	2367.02
SFRSCC1	70.25	2.83	0.89	3.89	2413.70
SFRSCC2	69	3.05	0.87	5.83	2401.24
SFRSCC3	67	3.61	0.84	2.08	2372.60
SFRSCC4	65.5	3.93	0.81	1.66	2360.80

The results in figure 3 show that all concretes exhibit slump flows in compliance with SCC requirements, with a uniform distribution of aggregates and fibers. The fiber-reinforced concretes with marble have a slightly reduced spread compared to the control concrete, which confirms the findings of Haddadou [20], Boulekbache [21], and Khaloo [18], who demonstrated that the addition of fibers decreases the spread of SCCs. This is also consistent with Groth's conclusions [22], which demonstrated that workability depends on the dosage and geometry of steel fibers, particularly their aspect ratio.

Figure 4 shows that the influence of fibers on the flow time (T500) is significant: the higher the fiber dosage, the higher the T500. This is explained by the overlapping of fibers, which creates blockage zones, thus delaying the flow. These observations confirm the findings of Hadaddou [20].

The results of the L-box test show that the highest filling value is achieved with the reference SCC (RSCC) and it decreases with the addition of fibers. This phenomenon, also observed by Haddadou [20], indicates that increasing the fiber content hinders the flow, leading to blockage, particularly for SCCF5. Nevertheless, all mixes exhibit filling rates that meet the AFGC [19] requirements, as illustrated in figure 5.

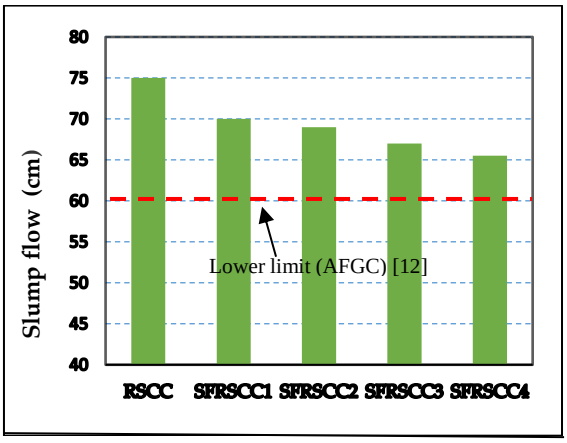

Figure 3: Slump flow values for the different self compacting concretes.

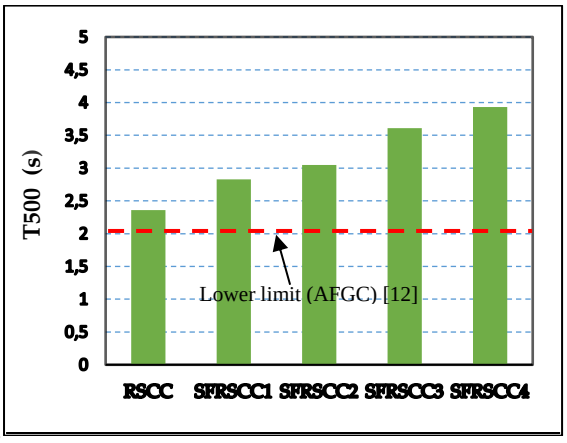

Figure 4: T500 time values for the different self compacting concretes.

The results of the sieve stability test show an improvement in stability with the addition of steel fibers. The highest value is recorded for the reference SCC, and it decreases with the incorporation of fibers, which is explained by the good adhesion between the paste and the fibers. None of the studied SCCs present a risk of static segregation, as the paste loss rate remains below 15% and meets the requirements (see Figure 6).
It should be noted that the bulk densities of the fiber-reinforced SCCs (SFRSCC) are almost identical to those of the fiber-free concrete, as the weight of the steel fibers is negligible compared to that of the aggregates. This result has also been observed in the work of Boutben [23].

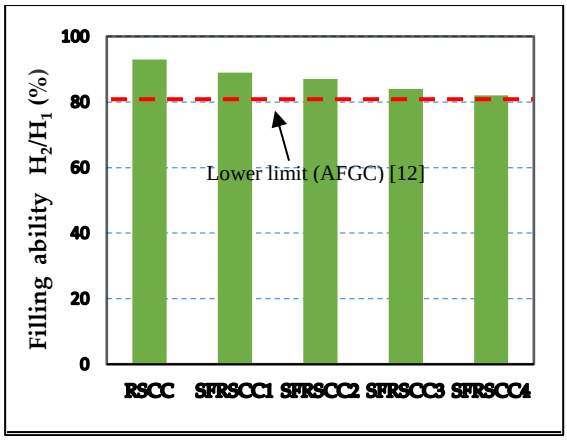

Figure 5: Variation in filling ability for the different SCCs

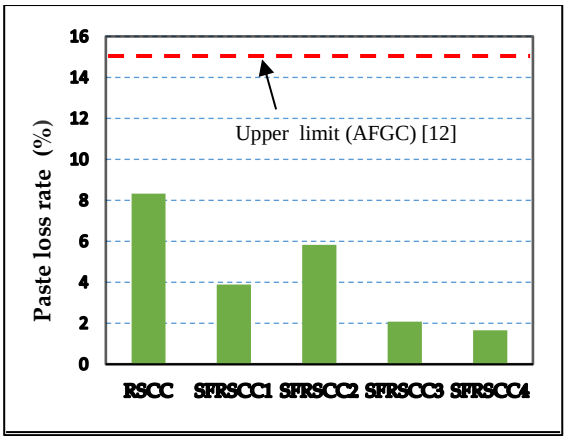

Figure 6: Variation in sieve stability for the different SCCs.

Regarding the mechanical characterization, as shown in figures 7 and 8, it is observed that after failure, the distribution of fibers is not homogeneous in the fiber-reinforced SCC specimens subjected to mechanical tests.

Figure 7: Distribution of fibers in the SCC specimens subjected to the bending test

Figure 8: Test method and specimen failure with 0.5% fiber in the case of the compression test

The results of the compressive and flexural strengths of the studied self compacting concretes are summarized in table 7.

Table 7: Results of the mechanical strengths of the studied self compacting concretes

Type of SCC	**Compressive strength (MPa)**	**Flexural strength (MPa)**
RSCC	37	5.15
SFRSCC1	38.3	5.55
SFRSCC2	39.2	5.81
SFRSCC3	40.6	6.08
SFRSCC4	41	6.34

Based on figure 9, a considerable improvement in flexural strength is observed following the introduction of fibers into the compositions of the self-compacting concretes. This figure shows that the fiber-reinforced SCC with 0.5% fibers exhibits a higher flexural strength compared to the fiber-reinforced SCC with 0.2% fibers, as well as to the control SCC.

A gain of approximately 23.10% was recorded compared to the control concrete for a fiber dosage of 0.5%. This increase is attributed to the good adhesion between the fibers and the concrete matrix. This result is often confirmed by other studies such as those by Grunewald [24], Gencel [25], Balaguru [26], and Deeb [27]. For example, it was shown by Gencel [25] that for a dosage of 30 kg/m³ of metallic fibers, the flexural strength increased by 51.7%.

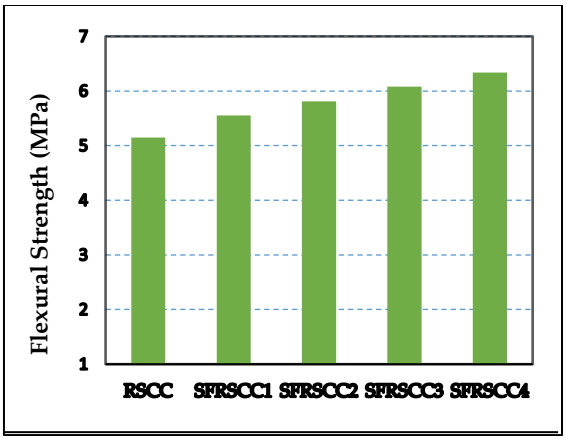

Figure 9: Variation in the flexural strength of the different self compacting concretes.

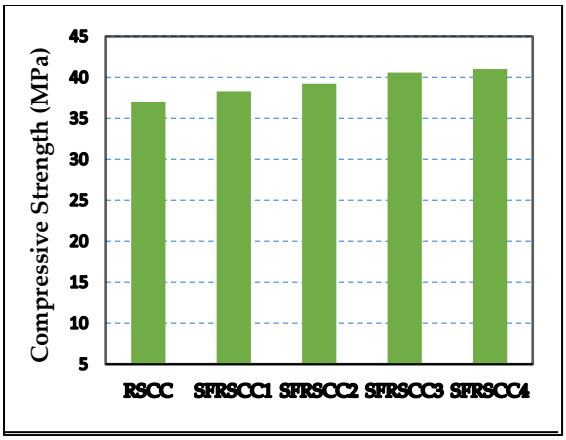

Figure 10: Variation in the compressive strength of the different self compacting concretes.

Figure 10 shows the variation in compressive strength as a function of fiber dosage. A slight increase in compressive strength of approximately 10.8% is observed compared to the control concrete for a fiber dosage of 0.5%. This result is consistent with the works of Gencel [25] and Madandoust [28], which have demonstrated that the increase in fiber dosage slightly influences compressive strength.

It should be noted that it is not only the increase in flexural strength that is aimed for, but also the ductile behavior that makes the use of fiber-reinforced concrete beneficial. Based on figures 11, 12, and 13, it can be concluded that the increase in fiber dosage improves ductility.
The failure of the control concrete is brittle; when the strength limit is reached, a sudden fracture is observed. This is explained by the low tensile strength of the concrete alone under the stresses developed in the tension zone of the flexural element. This failure is illustrated in figure 11.

Figure 11: Failure of the control concrete (Brittle failure at mid-span).

For the non-fiber-reinforced concretes, the specimen is broken with a crack initiated at the lower fiber level. The crack propagates vertically upward, dividing the specimen into two parts.

According to figure 12, the failure mode observed in the fiber-reinforced specimens with 0.2%-0.3%-0.4% fibers by volume of the concrete matrix shows a significant improvement regarding the initiation of microcracks. This is explained by the presence of fibers, which serve to stitch the microcracks and hinder the rapid development of the main crack opening.

Figure 12: Ductile failure mode for SFRSCC1, SFRSCC2 and SFRSCC3.

Figure 13: Densification of cracks and ductile failure for the case of SFRSCC4 (0.5% fibers).

Under the effect of a redistribution of tensile stresses in the bending zone, the main crack is accompanied by other independent cracks with significant openings or by small secondary cracks originating from the main crack.
According to figure 13, for the fiber-reinforced self-compacting concrete specimens with 0.5% fibers by volume of the concrete, a more ductile failure is observed, characterized by the presence of a main crack of lesser thickness at the supports, as well as a densification of microcracks across the entire normal face of the flexed element. This is explained by the high fiber content in the concrete matrix.

In addition to its technical advantages, the use of marble powder as a partial replacement in the formulations of steel fiber-reinforced self-compacting concrete (SFRSCC) also offers significant environmental benefits that deserve to be discussed. The use of marble powder as a partial substitute for cement or fines in self-compacting concrete (SCC) presents notable environmental advantages. Firstly, it valorizes an industrial by-product from marble cutting and polishing, thereby reducing the amount of waste sent to landfills and limiting environmental pollution. Secondly, replacing cement with marble powder helps reduce CO2 emissions associated with cement production, an energy-intensive process responsible for approximately 7% of global CO2 emissions. Thirdly, by integrating a local material such as marble powder, which is particularly abundant in Algeria, the carbon footprint associated with transporting imported raw materials is reduced. Lastly, this approach promotes a circular economy by incorporating industrial by-products into innovative concrete formulations while preserving natural resources such as limestone and aggregates. These benefits contribute to making SCC more sustainable and environmentally friendly.

However, the implementation of these innovative formulations raises important questions regarding their practical feasibility, particularly in terms of costs, logistics, and large-scale adoption in real-world projects. The feasibility of steel fiber-reinforced self-compacting concrete (SFRSCC) formulations based on marble powder in Algeria appears promising but comes with certain challenges. The abundant availability of marble powder, a by-product of the local industry, provides an economic advantage by reducing raw material costs. This valorization also limits transportation expenses, as the powder is often produced near construction sites. However, the high cost of steel fibers remains a barrier, potentially hindering their large-scale adoption. In terms of logistics, the supply chain required to uniformly integrate these materials into SCC demands optimal coordination, particularly to ensure consistent powder quality. Moreover, companies must overcome resistance to adopting innovative formulations, which are often perceived as risky. Finally, awareness campaigns and real-world testing are necessary to demonstrate the performance and durability of these SFRSCC formulations, thereby facilitating their integration into local projects.

4 Conclusion

The results obtained in this study highlight the significant influence of incorporating metallic fibers and marble powder on the rheological and mechanical properties of self-compacting concrete (SCC). From a rheological perspective, the addition of marble powder notably improved the fluidity and workability of the mixes, which is essential for ensuring proper distribution of aggregates and homogeneity within the concrete matrix. However, the introduction of metallic fibers, although causing a slight decrease in cone slump, showed a positive effect on the stability of the mixes, minimizing the risk of segregation. The observed reduction in cone slump is offset by an increase in flow time and improved resistance to segregation, especially for high fiber dosages.

On the mechanical side, metallic fibers significantly enhanced flexural strength and ductility. Specifically, a 23% increase in flexural strength was observed with a fiber dosage of 0.5%, confirming their role in bridging cracks and distributing stresses. In contrast, compressive strength was only slightly affected by the addition of fibers, with a modest increase of 10.8%. This suggests that while fibers are particularly effective in improving tensile behavior and ductility, their impact on compressive strength remains limited.
The change in failure mode, from brittle to ductile behavior, illustrates the contribution of metallic fibers in controlling crack propagation after the initial microcracks appear. This shift in behavior is crucial for structural applications where energy dissipation under load is required, particularly in environments subjected to dynamic loading.

This study advances knowledge in the field by highlighting the synergy between metallic fibers and marble powder, which optimizes both the rheological and mechanical properties of self-compacting concrete (SCC), while opening up promising perspectives for the design of more durable and high-performance concrete, leveraging local materials and industrial by-products.
To further explore these results, microstructural studies could be conducted to better understand the interactions between the cement matrix, metallic fibers, and marble powder, particularly regarding adhesion and microcrack propagation. A finer optimization of fiber and marble powder dosages could improve both rheology and mechanical properties simultaneously.

Moreover, testing these formulations in structural elements subjected to dynamic loads or harsh environmental conditions would validate their potential in real-world applications. The exploration of hybrid formulations combining metallic and synthetic fibers could also offer an interesting compromise between rheology and mechanical performance. Thus, the findings of this research lay the foundation for the sustainable development of fiber-reinforced self-compacting concrete (SCC), meeting the growing demands of the construction industry in terms of performance and durability.

References

[1] V. Jarugumalli and al. (2022) "The flow properties of self compacting concrete with marble waste powder as a partial substitute for cement" Materials Today: Proceeding 52, 617-621.

[2] J. Ahmad and al. (2024) "Waste marble based self compacting concrete reinforced with steel fiber exposed to aggressive environment" Journal of Building Engineering 81, 108142.

[3] Mr.Ch.Rajendra Prasad and al. (2021) « Experimental studies on steel fiber reinforced self compacting concrete by partial replacement of cement with marble dust » Turkish On line Journal of Qualitative Inquiry (TOJQI), Vol.12, Issue 9, pp: 486-499.

[4] A. Rajesh (2018) « Effect of partial replacement of cement with marble dust powder using steel fiber on strength parameters of self compacting concrete » International Journal of Management Technology and Engineering, Vol.8, Issue 9, pp: 1336-1343.

[5] T.A.Wani and al. (2022) "Study on fresh properties, mechanical properties and microstructure behavior of fiber reinforced self compacting concrete: A review" Materials Today: Proceeding 62, 6663-6670.

[6] B.C.Xavier and al. (2021) « Study of three distinct self compacting concrete containing marble/granite powder and hooked-end-steel fiber contents » Journal of Composite Materials, Vol.55, Issue 20.

[7] S.Vijaya Kumar an al. (2022) "Mathematical model for the impact strength of triple blended steel fiber self compacting concrete based on the experimental study" Materials Today: Proceeding 60, 579-581.

[8] P.Velci Shridevi and al. (2024) "Strength characteristic of fiber reinforced self compacting concrete using marble sludge powder" Materials Today: Proceeding, Article in press, https://doi.org/10.1016/j.matpr.2023.12.004.

[9] N. Haddadou and al. (2015) « Fresh and hardened properties of self compacting concrete with different mineral additions and fibers » Journal Build. Mater. Struct. 2: 41-50.

[10] N. Haddadou and al. (2021) « The effect of steel fiber size on the properties of fresh and hardened self compacting concrete incorporating marble powder » SSP-Journal of Civil Engineering, Vol. 16, Issue 1.

[11] J.Ahmad and al. (2023) « Mechanical performance of waste marble based self compacting concrete reinforced with steel fiber (part 1) » Journal of Building Engineering, Vol 78,107574.

[12] A.Khaloo et al. (2014) «Mechanical performance of self-compacting concrete reinforced

with steel fibers » Construction and Building Materials. Volume 51.31, Pages 179-186.

[13] M. Tabatabaeian and al. (2017) «Experimental investigation on effects of hybrid fibers on rheological, mechanical, and durability properties of high-strength SCC» Construction and Building Materials Volume 147, 30, pp 497-509.

[14] J.Ahmad and al. (2023) « Self compacting concrete with partially substitution of waste marble : A review » International Journal of Concrete Structures and Materials 17:25.

[15] D.Gueciouer and al. (2022) « Rheological and mechanical optimization of a steel fiber reinforced self compacting concrete using the design of experiments method » European Journal of Environmental and Civil Engineering, Vol.26, Issue 3.

[16] L.Keval and al. (2017)« Performance evaluation of self compacting concrete containing mound ash & steel fibre » IJARIIE-ISSN(O)-2395-4396 Vol-3 Issue-2.

[17] C.Frazão and al. (2015) «Durability of steel fiber reinforced self-compacting concrete»

Construction and Building Materials 80, pp155–166.

[18] T.Paul and al (2016) «Experimental study on self compacting concrete with steel fibre reinforcement» International Journal of Science Engineering and Technology Research (IJSETR) Volume 5, Issue 4.

[19] French Association of Civil Engineering (AFGC) (2000) "Self-Compacting Concretes"

Provisional Recommendations, Scientific and Technical Documents.

[20] N.Haddadou (2014) «The effect of hybrid steel fiber on the properties of fresh and hardened self-compacting concrete » J. Build. Mater. Struct.1, pp65-76.

[21] B. Boulekbache (2009) "Influence of the Rheology of Fiber-Reinforced Concrete on Their Mechanical Properties," 1st International Conference on Sustainable Built Environment Infrastructures in Developing Countries, ENSET Oran, Algeria.

[22] P.Groth (2000) "Fiber reinforced concrete - Fracture mechanics methods applied on self-compacting concrete and energetically modified binders", PhD-thesis, Department of Civil and Mining Engineering, Lulea University of Technology.

[23] M. Bouteben (2015) "Effect of the Incorporation and Dosage of Metallic Fibers on the Characteristics of Glass Powder-Based HPC," Master's Thesis, University of Skikda, Algeria

[24] S. Grunewald and al. (2001) « Prameter study on the influence of steel fibers and coarse aggregate content on the fresh properties of self compacting concrete" Cement and concrete research, vol 31, pp. 17931798.

[25]O.Gencel et al. (2011) « Workability and Mechanical Performance of Steel Fiber-Reinforced Self-Compacting Concrete with Fly Ash » Composite Interfaces 18, pp169-184.

[26] P. Balaguru and al. (2004) "High performance fiber reinforced concrete mixture proportions with high fiber volume fractions" ACI Materials Journal, 101, pp. 286-286.

[27] R.Deeb and al. (2012) "Development of self compacting high and ultra high performance concretes with and without steel fibers" Cement and concrete composites, 34, pp.185-190.

[28] R.Madandoust and al. (2015) « Assessment of factors influencing mechanical properties of steel fiber reinf-orced self-compacting concrete » Materials and Design 83, pp 284–294.