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Effect of Steel Fibers on the Mechanical Properties of Mortars

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Abstract

The reinforcement of cement-based materials by fibers has currently become an interesting solution in order to improve their qualities and their structural resistance. In fact, there are several types of fibers, differing according to their origins, such as polymer, metallic or ceramics. This study aims to examine in particular, the effect of the addition of steel (metallic) fibers on the mechanical properties of cement-based mortars. For this, an experimental approach described in this work was followed in order to achieve this objective. The fibers were introduced into the mixture during mixing with varying percentages from 0.4 to 3% of the cement mass, and the mechanical strengths (Tensile and compressive) were measured. The results showed that the introduction of steel fibers into a mortar gives compressive and tensile strength results higher than those of control mortars, and that the best percentages in terms of resistance and economy are between 0, 7 and 1.9% of the mass of cement. Indeed, we recorded an increase in compressive strength ranging from 15% to 54% (up to approximately 70 MPa) and an increase in tensile strength ranging from 29 to 57% (up to approximately 10 MPa). The addition of fiber therefore makes it possible to increase the resistance of the mortar specimens and the appearance of cracks without rupture or destruction in the case of the bending test in comparison with ordinary mortars specimens.

Keywords: *Concrete, Mortar, Strength, Steel Fibers, Tension, Compression.*

1. INTRODUCTION

Concrete is widely used in construction, however, we known to have low tensile strength, low stiffness, low ductility, low energy of absorption of deformation, combined with brittle behavior which results in sudden rupture by pulling without warning (Altun et al.,2007, Pesaran et al.,2011, Kiranbala et al.,2013, Joshi et al.,2016, Saand et al.,2016, Saqib et al. ,2020), moreover, when the concrete is hardened, shrinkage cracks appear on its surface, which limit its applications (Frazão et al.,2013, Saand et al.,2016).

The concrete then requires some form of tensile reinforcement to compensate for its brittle behavior and improve its tensile strength and deformability (Belmahi et al.2018a; Belmahi et al., 2019;), therefore, to improve these deficiencies in concrete, a daily variety of fibrous materials such as straw, long wood fibers, steel fibers, plastic, glass and other natural materials are now used in concrete for better structural and service applications (Katzer, 2006, Pesaran et al., 2011 , Frazão et al., 2013, Saand et al., 2016).

Unlike conventional rebars, which are specifically designed and placed in the tensile zone of the concrete member, the fibers are thin, short and randomly distributed throughout the concrete member (Pesaran et al., 2011). Their role is to fill the cracks that develop, provide a

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certain "ductility" post-cracking, allow the FRC to withstand significant stresses on a relatively large deformation capacity translated by a considerable increase in the total energy absorbed, an increase fatigue strength, flexural strength, shear strength and impact strength, improved durability and increased concrete toughness, it also increases the workability of concrete (Altun et al., 2007, Frazão et al., 2013, Kiranbala et al., 2013; Velayutham et al., 2014, Bazgir.2016; Joshi et al., 2016, Saqib et al., 2020; Muhammad et al., 2022,).

The work developed in this study consists in examining the effect of the addition of steel fibers on the mechanical properties of the mortars in particular the tensile strength and the compressive strength as well as determining the ideal fiber dosages.

For this, an experimental approach described below was followed in order to achieve this objective

2. MATERIALS

Cement: The cement used is a CEM II / A-L composite cement with a resistance of 42.5 N, manufactured at the AMOUDA factory in "EL BAYDHA" Laghouat, Algeria. It is gray cement in accordance with the Algerian standard NA 442 as well as the European standard EN 197 -1 (Table1). It is used for reinforced concrete works, self-compacting concrete, paving, industrial floors, screeds, foundations, underground works and concrete roads and pavements.

Table 1: Chemical and physico-mechanical properties of cement

Chemical properties AN 5042 (EN 196-2)	Physico-mechanical properties AN 230 (en 196-3) / AN 234 (EN 196-1)	
S03 ≤ 3.5% chloride ≤ 0.1%	Setting time > 60 min	Compressive strength 2 jours>10 Mpa 28 jours > 42.5 Mpa

Sand: The sand used is natural sand, from the quarry of El Galta Laghouat, its characteristics are as follows: Apparent density (1450 Kg/m3), absolute (2500 Kg/m3), particle size class 0/3 and the sand equivalent equal to 78% (it is a clean sand with a low proportion of fine clay which is perfectly suitable for high quality concrete) The results are in line with the work of Belmahi et al., 2018b & 2021).

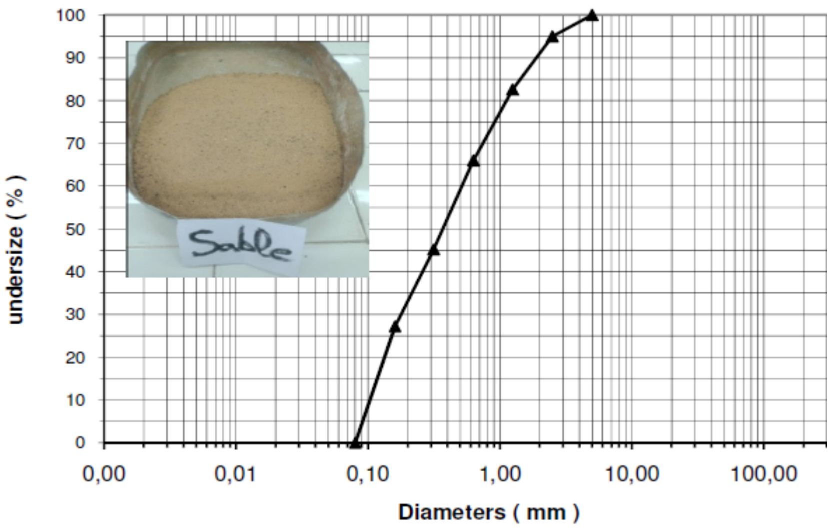

Fig 1: particle size analysis test of sand Galta Laghouat

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Adjuvant: the adjuvant used is MEDAFLOW 145. It is a high water-reducing super plasticizer from the new generation of adjuvants. It is designed based on modified polyether carboxylates and it makes it possible to obtain very high quality concretes and mortars. Its recommended dosage range is 0.3 to 2.0% of the weight of cement, i.e. 0.33L to 1.8L per 100 kg of cement. It is accordance with the Algerian standard NA 774 as well as the European standard EN 934-2 (Table 2).

Table 2: Characteristic of the adjuvant used EN 934-2 & AN 774

stat	Color	PH	Density	chloride content
liquid	brown	5-6	1.065	<1g/l

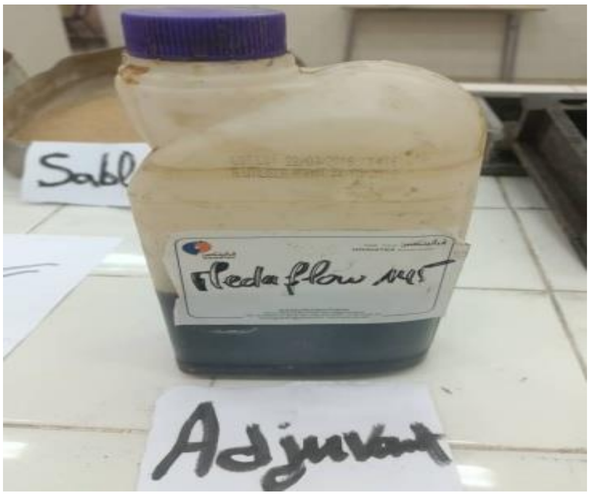

Fig 2: Adjuvant MEDAFLOW 145

Steel fibers: the steel fibers used are from the FIBERTEK brand of the Hassnaoui GSH group which are obtained by cold drawing high-strength steel wire with special shaping to obtain the best anchorage over their entire length. FIBERTEK-A fibers are intended for structural reinforcement. It makes it possible to obtain concrete and mortar with high resistance to shocks and vibrations and to concentrated loads. The uniform distribution of fibers in the mixture makes it possible to use FIBERTEK to replace secondary reinforcement and containment of crack propagation.

Fig 3: Steel fibers

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The characteristics of the steel fibers are summarized in the table 3.

Table 3: Characteristics of the steel fibers used (FIBERTEK A).

Longueur (mm)[1]	Diamètre fil (mm)[2]	Rapport d'aspect (1/2)	Format	Section transversale	Tension à la rupture à la traction (N/mm²):	Allongement à la rupture
50 ± 10 %	1 ± 10 %	(L/de) 50	à crochet	circulaire	1100-2700	< 4 %

3. PROCEDURE

The mortars made are of the 1/2 type (the mass of the sand is equal to twice the mass of the CEM II /A-L cement with a resistance of 42.5 N) mixed with water and an admixture. The specimens produced are prismatic specimens of dimension (4×4×16) cm3. To achieve the objective of the study, we made in the first step a reference mortar (without additions) whose quantity of water and admixture were adjusted experimentally in order to obtain a normal consistency (table 1). Subsequently, we introduced the quantity of steel fibers weighed directly into the mixer (at the time of mixing with the other ingredients). The problem may lie in the formation of sea urchins (or fiber balls), due to the fact that the fibers naturally tend to agglomerate during mixing as a result of reciprocal friction. So, this phenomenon to be avoided during this step. The compositions selected are summarized in Table 4.

Table 4: Mortars compositions.

Mortars	Cement (g)	Sand (g)	E/C	Adjuvant %	Steel Fiber %
Witness	675	1350	0,35	0,7	**00**
1	675	1350	0,35	0,7	**0 ,4**
2	675	1350	0,35	0,7	**0,7**
3	675	1350	0,35	0,7	**1,1**
4	675	1350	0,35	0,7	**1,5**
5	675	1350	0,35	0,7	**1,9**
6	675	1350	0,35	0,7	**2 ,2**
7	675	1350	0,35	0,7	**2 ,6**
8	675	1350	0,35	0,7	**3,0**

The mortars are made according to the requirements of the Algerian standard NA442 and the European standard EN 197-1 (mixing, filling and packaging) (figure 2).

Fig 4: Mixing of mortar, filling of molds and conservation of mortar specimens

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4. RESULTS

After 28 days of storage and hardening of the specimens, they were subjected to mechanical bending and compression tests (figure.5) using machines according to the standards (NA 234, EN 12615 and EN 1015-11).

Fig 5: Bending and compression tests.

The results obtained are summarized in Table 5, figure 6 and 7.

Table 5: Results of mechanical tests

Steel Fiber		Tensile strength (MPa)	Compressive strength (MPa)
(g)	%		
0	0	6,32	44,23
2,5	0,4	9,36	55,78
5	0,7	9,48	65,00
7,5	1,1	9,95	68,17
10	1,5	9,83	68,32
12,5	1,9	9,13	61,56
15	2,2	8,93	59,42
17,5	2,6	8,78	55,61
20	3,0	8,19	51,10

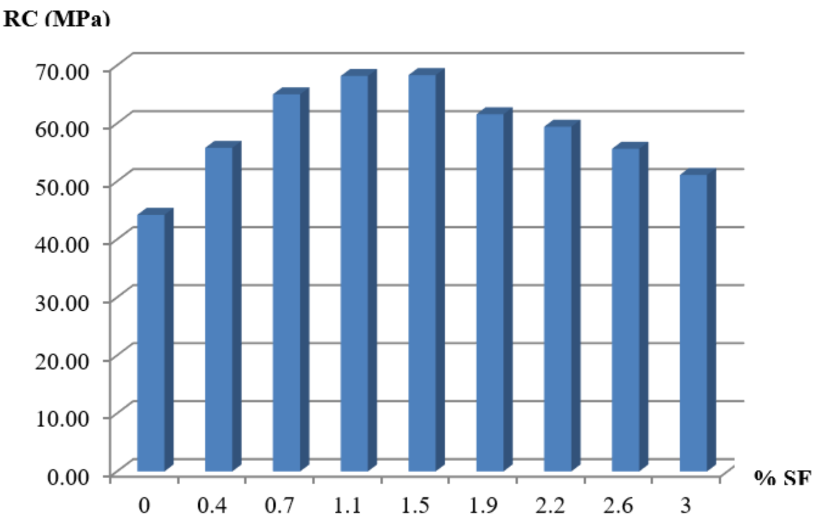

Fig 6: Compressive strength (MPa).

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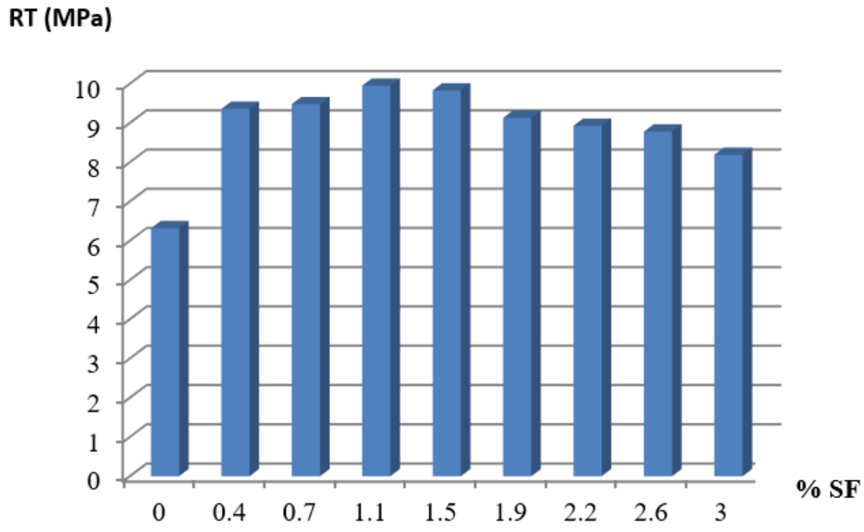

Fig 7: Tensile strength (MPa).

According to the results above, we have generally observed good mechanical strength, all the values are higher than that of the control mortar: Compressive strengths between 51 and 68 MPa (figure 4), which corresponds to an increase of approximately 15 to 54% compared to the control mortar and tensile strengths of between 8.18 and 9.95 MPa (figure 5), which corresponds to an increase of 29 to 57% compared to the control mortar. It should be noted that all the results obtained in this study are good. Compared to the results of the standard or ordinary mortar. Thus, the best steel fiber dosages taking into account the resistance and the manufacturing costs are between 0.7 and 1.9% of the cement mass. We have observed through experience that the steel fibers reinforce the cohesion of the mortar. Thus, after applying a tensile force to a sample of ordinary mortar, it splits into two parts as shown in Figure 6 while the steel fiber reinforced mortar breaks and the two parts remain connected and bound together by the steel fibers as shown in figure 7, which improves stability and safety during the post-crack phase.

Fig 6: Failure of an ordinary mortar subjected to tension by bending.

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Fig 7: Failure of a mortar reinforced with steel fibers subjected to tension by bending

5. CONCLUSION

The mechanical properties were improved during the post-crack phase translated by an increase in ductility and will be generated on the durability of the mortar following the absorption of the applied stresses. We can also say that fibers help reduce or eliminate the need in traditional reinforcing steels.

Also in terms of dosage we conclude that an excessive dosage of fiber is not always the right choice. The fractions proposed in this work have proven that the latter must be between 0.7 and 1.9% of the mass of cement, therefore the methods of introducing metal fibers into the mixture are very important and depend on the volume of the concrete. , implementation and expected objectives.

A study can be carried out and compared to this work; the fibers are introduced manually and in layers when filling the concrete or mortar into the molds or into the formwork instead of putting them directly into the mixer. This method can give better homogeneity and completely avoid the formation of sea urchins (or fiber balls).

References

1) Abdullah Saand, Muhammad Salman Afridi, Manthar Ali Kerio, Daddan khan Bangwar (2016), mechanical properties of concrete reinforced with steel fibers extracted from waste tyres. Sci.Int. (Lahore), 28(4), 3877-3880. ISSN 1013-5316.

2) Hamid Pesaran Behbahani, Behzad Nematollahi, Majid Farasatpour. (2011). Steel Fiber Reinforced Concrete: A Review, ICSECM, Kandy-SriLanka.

3) Saqib ALI, Haresh KUMAR, Samar Hussain RIZVI, Muhammad Saleem, RAZA, Jawaid Kamal ANSARI. (2020). Effects of steel fibres on fresh and hardened properties of cement concrete. Civil and environmental engineering reports. CEER 2020; 30 (3): 0186-0199, DOI: 10.2478/ceer-2020-0039. E-ISSN 2450-8594.

4) Kiranbala Devi,T. Bishworjit Singh (2013). International Journal of Engineering Research & Technology (IJERT), Vol. 2 Issue 10, ISSN: 2278-0181.

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5) Fatih Altun, Tefaruk Haktanir, Kamura Ari (2007). Effects of steel fiber addition on mechanical properties of concrete and RC beams. Construction and Building Materials 21 654–661.

6) Avinash Joshi, Pradeep reddy, Punith kumar and Pramod hatker. (2016). Experimental work on steel fibre reinforced concrete. International Journal of Scientific & Engineering Research, Volume 7, Issue 10, October ISSN 2229-5518.

7) Cristina Frazão, Aires Camões, Joaquim Barros and Delfina Gonçalves (2013). Durability of steel fiber reinforced self-compacting concrete. Twin Covilhã International Conferences 5th Int'l Conference on The Concrete Future, 26-29, Covilhã, Portugal.

8) Samir Belmahi., Mohamed Zidour, Mustapha, Meradjah, Tayeb & Dihaj, A. (2018 a). Analysis of boundary conditions effects on vibration of nanobeam in a polymeric matrix. Structural Engineering and Mechanics, 67(5), 517-525.

9) Belmahi, S., Zidour, M., & Meradjah, M. (2019). Small-scale effect on the forced vibration of a nano beam embedded an elastic medium using nonlocal elasticity theory. Advances in Aircraft and Spacecraft Science, 6(1), 1-18.

10) Jacek Katzer (2006). Steel Fibers and Steel Fiber Reinforced Concrete in Civil Engineering. The Pacific Journal of Science and Technology Volume 7. Number 1. (Spring).

11) Ahmad Bazgir. (2016). The Behaviour of Steel Fibre Reinforced Concrete Material and its Effect on Impact Resistance of Slabs. Master of Philosophy in Structural Engineering. City University London.

12) G. Velayutham, C.B. Cheah. (2014). The Effects of Steel Fibre on the Mechanical Strength and Durability of Steel Fibre Reinforced High Strength Concrete (SFRHSC) Subjected to Normal and Hygrothermal Curing. MATEC Web of Conferences 10. 02004.

13) Muhammad Nasir Amin, Waqas Ahmad, Kaffayatullah Khan and Ayaz Ahmad. (2022). Steel Fiber-Reinforced Concrete: A Systematic Review of the Research Progress and Knowledge Mapping. Materials, 15, 6155. https://doi.org/10.3390/ma15176155.

14) Belmahi samir, Mohamed Zidour, Tayeb Bensatllah (2018 b). Comportement mécanique des mortiers de chamotte à base d'un mélange de ciment- filler calcaire. Lebanese Science Journal, LSJ. 19 (1), 95-104.

15) Samir Belmahi, Zidour Mohamed, and Haddi Abdelkader, (2021), Valuation of foundry sand in the construction sector. Lebanese Science Journal, Vol. 22, No. 1, 2021.