Dimensional Variations of Cement Matrices in the Presence of Metal Fibers

Fatima Setti, Ezziane Karim, Setti Bakhti, Negadi Kheira

Abstract**—**The objective of this study is to present and to analyze the feasibility of using steel fibers as reinforcement in the cementations matrix to minimize the effect of free shrinkage which is a major cause of cracks that have can observe on concrete structures, also to improve the mechanical resistances of this concrete reinforced. The experimental study was performed on specimens with geometric characteristics adapted to the testing. The tests of shrinkage apply on prismatic specimens, equipped with rods fixed to the ends with different dosages of fibers, it should be noted that the fibers used are hooked end of 50mm length and 67 slenderness. The results show that the compressive strength and flexural strength increases as the degree of incorporation of fibbers increases. And the shrinkage deformations are generally less important for fibers-reinforced concrete to those appearing in the concrete without fibers.

Keywords**—**Concrete, Steel fibers, Compression, Flexural, Deformation.

I. Introduction

CONCRETE with steel fibers has become one of the most used special concrete, attracting researchers reflection. Its mechanical behavior is one of the areas most invested and remains to our own day to conquer. The fragile behavior of concrete can be avoided by incorporating steel fibers to the initial composition of the concrete; they play a reinforcing role which compensates fragility [1], [2]. After bending tests, Houari [3] found that the addition of 1% steel fibers increased greatly flexural strength which is consistent with other results [4]. The improvement of strength of concrete reinforced with steel fibers can not only improve the behavior in flexure and tension, but also the compressive strength of the concrete. Gopalaratnan et al. [5] in their results observed in static compression, that the presence of steel fibers in the matrix increases the tensile strength of 35% for 1.5% by volume of fibers, even Damgir et al. [6] found that the compressive strength increase when the volume of fibers increase, this improvement achieved 21.2% at 28 days for a dosage of 2% fibers. Further results on mortars [7] reported the resistance decreases for fibers content greater than 1.25%.

The drying shrinkage is a physico-chemical phenomenon the most important in the mortar and implicitly in the concrete. This phenomenon, which boils down to a macroscopic deformation deferred occurring in the absence of charge, appears from the first moments of the life of the material and continues during all stages of maturation. The shrinkage phenomenon engenders significant constraints which can then lead to cracking. But today a new technique can be applied in an attempt to remedy that negative aspect consists that to the inclusion of steel fibers in the matrix, they can participate positively in reducing shrinkage [8], [9]. According to Mangat et al. [8], the fibers are used for reducing the detrimental effects of cracking due to shrinkage. The fibers act in three ways:

– They allow multiple cracks close by blocking macrocracks
– They allow tensile stresses to be redistributed through cracks,
– The force transfer occurs for a longer time by the retarding and the sewing cracks.

Abdou and Houari [10] in their work on two types of fibers show that the fibers reduce the shrinkage, the decrease is about 16% for industrial fibers, and 20% for shavings compared to the control mortar, and that after a long time, the action of fiber is more accurate and mortars fibers stabilize faster than mortars without fibers. In the same way, Beddar [11] notes from his studies that the metal fibers reduce shrinkage. This decrease is of the order of 16% compared to a mortar without fibers at 28 days, for a proportion of 0.5% fiber volume. But with 1% fiber volume, this decrease varies between 11 to 13%. Chern et al. [12] observed that the drying shrinkage is slightly lower for fiber concrete compared to concrete without fibers. The same applies to other results [13] showed that the addition of 2% by volume of steel fibers reduces the free shrinkage of approximately 20% for concrete with compressive strength of 45 MPa and 65 then the shrinkage of the concrete with a strength of 30 MPa was not affected. This experimental study aims to evaluate the influence of the use of steel fibers on the dimensional variations of reinforced concrete elements and compared with that obtained with ordinary concrete.

II. Experimental Program

A. Constituents of Studied Concretes

1) Cement: The cement used is of type CPJ-CEM II / A 42.5 produced in the factory of Chlef. Its density is 3.1 while its specific surface area of 3700cm^2/g, the chemical, mineralogical and its composition are presented in Table I.

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TABLE I
COMPOSITION OF THE CEMENT USED

Chemical Composition (%)							
SiO2	Al2O3	Fe2O3	CAD	MgO	SO3	K2O	PAF
20.58	4.90	4.70	62.8	0.63	2.28	0.42	1.00
Mineralogical Composition (%)							
C3S	C2S	C3A	C4AF				
41.8	33.3	5.1	10.7				
Composition of cement (%)							
Clinker	Limestone	Gypsum					
86.5	10	3.5					

2) Aggregates: The aggregates are composed of rolled sand from Oued Chlef, whose fineness modulus Mf = 2.42, an apparent density of 1.63 and a sand equivalent Es = 89.74%. This allows you to say that the sand is clean and that the adhesion properties and the plasticity of the clay are not to be feared. The gravel used is a crushed gravel of the career of Oued Fodda to the region of Chlef (Algeria), and that is usually used in the current concrete. Table II presents the characteristics of the gravel used. The granulometric curves of the two components (sand, gravel) are represented on the Fig. 1.

3) Adjuvant: In order to check the maneuverability of the concrete and to keep an even consistency while inserting the steel fibers, it was used superplastifiant high reducer water manufactured by the company of Algeria Granitex marketed under the name of MEDAFLOW 30. It is designed based on poly carboxylates which significantly improve the properties of the concrete. The characteristics of the latter are represented in Table III.

4) Mixing Water: The water used in this case is supposed potable water from the tap and contains none harmful impurity.

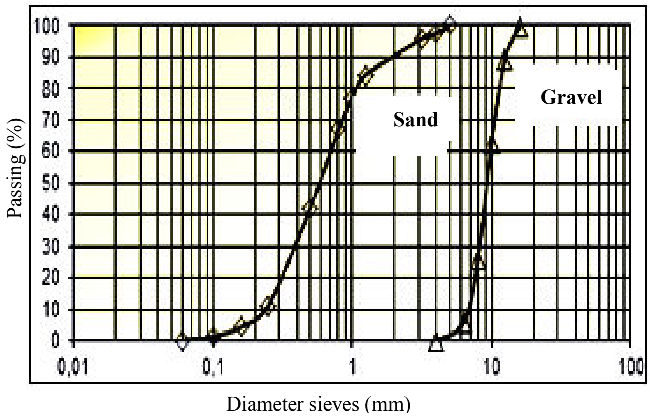

Fig. 1 Granulometric curves of sand and gravel

TABLE II
CHARACTERISTICS OF *THE GRAVEL USED*

The impurities	1.2 %
Coefficient Los Angeles	24
Volumetric coefficient	0.27
Absolute Density	2.61
Apparent Density	1.3

TABLE III
CHARACTERISTICS *OF SUPERPLASTIFIANT MEDAFLOW 30*

Form	Liquid
Color	Yellowish
PH	6- 6.5
Density	1.07 ± 0.01
Chlorine Content	< 1G/l
Dry Extract	30

5) Fibers: The fibers used are fibers HE + + 75/50 to a high carbon content. They are manufactured from drawn wire cold and are presented in cylindrical form and provided with end hooks. Fig. 2 represents the type of fiber used. And the geometrical characteristics of the fibers used are given in the Table IV.

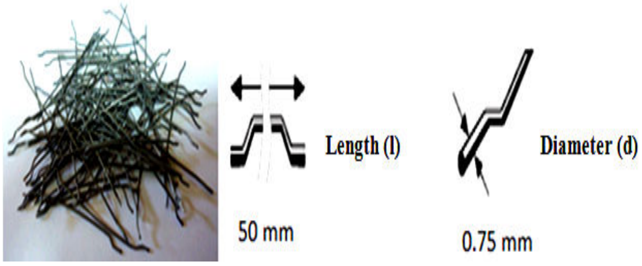

Fig. 2 Arcelor Mittal fibers of type HE + + 75/50

TABLE IV
CHARACTERISTICS OF METALLIC FIBERS HE++ 75/50

Form	Length (mm)	Diameter (mm)	Slenderness Ratio (l/d)	Tensile Strength (MPa)	Fiber Length by 10 kg (m)	Number of fibers per kg
	50	0.75	67	1900	2885	5700

B. Preparation of Test Specimens and Test Procedure

Workability tests are performed in the laboratory to optimize the preliminary composition found by the method of Dreux Gorisse, setting the W / C ratio of 0.45 with a dosage of 400 kg/m3 cement and varying S / G. This preliminary formulation must be optimized according to the practical method of Baron-Lesage. With this method, we tested four mixtures with S / G different (0.5, 0.6, 0.7, 0.8) to find the optimal value giving the best workability. The results are shown in Fig. 3. Found the optimal value coincides with the value obtained by the method Dreux Gorisse.

The mixtures were prepared with volume fractions of 0.5, 1, and 1.5% fiber (relative to the total volume of the concrete). Preparation of test specimens 7x7x28cm is performed according to the standard NF P 18-400. Mixing is carried out using a mixer whose total mixing time is 3 minutes. The vibration was carried out using vibrating table adjustable vibration amplitude. The samples were demolded after one day and then stored in water at -20°C until the day of the test. The tests are the tensile test by three-point bending and compression test on the half-prism resulting from the first test.

The experimental implementation is to conduct tests for measuring free shrinkage on prismatic specimens, pocket attached to the ends of stems (Fig. 4). The test specimens are dried in the open air after demolding, and isolated at both ends to avoid edge effects. Measurements began at a day of age using a comparator accuracy of 0.001mm.

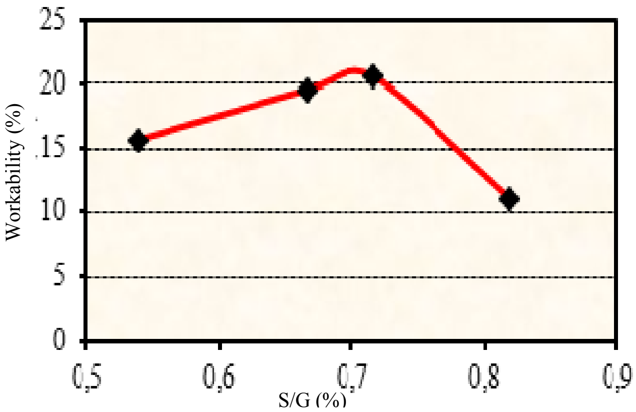

Fig. 3 Search for optimal compactness

Fig. 4 Disposition of test pieces when testing shrinkage

Two specimens were used for each type of concrete to measure free shrinkage. Thus a comparison at different times t, the variation in the shortening of a specimen 7x7x28 cm, relative to its value at time t0 (1 day).

III. Results Analysis

A. Flexural Tensile Strength

Fig. 5 shows that the flexural strength of the concrete increases versus time, and the addition of steel fibers engender a significant increase such as to obtain a resistance value double in the presence of 1.5% fiber. For concrete containing 1% steel fibers, its flexural strength is improved by 62%. The improvement provided by the addition of fibers on the mechanical behavior flexural tensile is due to participation of the fibers to the seam cracking.

B. Compressive Strength

From Fig. 6, it is found that the compressive strength evolves according of time; whatever the dosage of the fibers used. The gain depends on the concentration and on the geometry of these fibers and achieved to 7 days, a maximum value of 11, 21 and 29% fiber volume dosage respectively of 0.5, 1 and 1.5%.

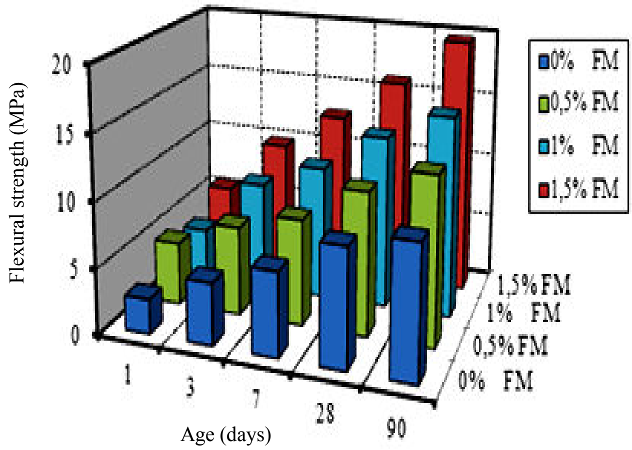

Fig. 5 Variation of the tensile strength in bending versus time

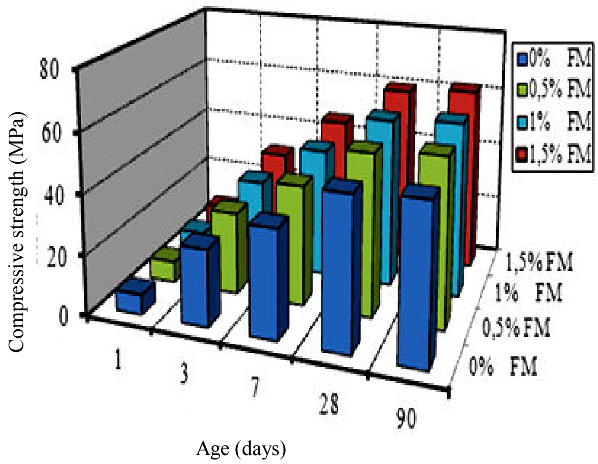

Fig. 6 Variation of the compressive strength versus time

This improvement in compressive strength is attributed to the mechanical adherence of the fibers which increases the ability to retard the formation of cracks and stop their spread. The compressive strength is often improved by the presence of metal fibers which contribute to reduce the appearance of cracks and their propagation. For the results, it was found that the strength gain compared to untreated control fiber concrete increases linearly with the quantity of fibers.

C. Relationship Tension-Compression

It is judicious, by studying the variations of the compressive strength of connect with the traction. For this, the converted results of the flexural strength in tension multiplying them by a coefficient of 0.6 which takes account of plastic deformation of the concrete in the pre rupture. The results are shown in

Fig. 7 where the variation is almost linear for all types of concrete.

D. Shrinkage

The average curves of two specimens of free shrinkage versus time are shown in Fig. 8. It can be seen from this figure that the shrinkage decreases as we increase the quantity of fibers. This decrease is of the order of 26, 39, 46% compared at a concrete without fibers at 28 days, respectively, for the proportions of 0.5, 1, 1.5% fibers volume.

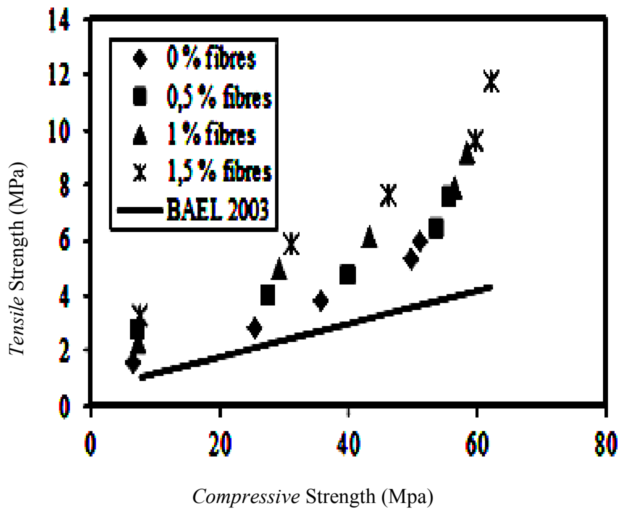

Fig. 7 Variation of the tensile strength as a function of the compression for different types of concretes

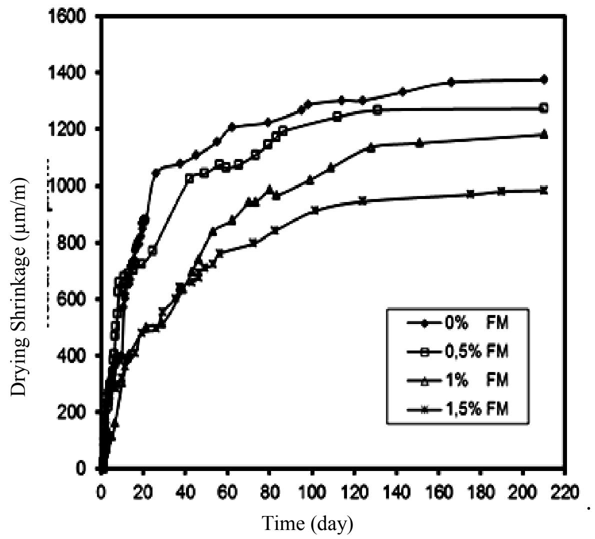

Fig. 8 Drying shrinkage of a concrete reinforced with metal fibers

The zone shrinkage values is narrow at the beginning of drying up to 45 days between the witness concrete and fibers reinforced concrete, and it is stretched after a long time. A long term action of the fibers is more significant where the shrinkage is prevented by increasing the mechanical properties of concrete, which increases the fiber adherence to the matrix. This, shrinkage of reinforced concrete stabilizes faster than the control concrete, as seen in Fig. 8.

We can clearly observe that as the rate of incorporation of fibers greater, the shrinkage is low compared to shrinkage of the reference concrete. At early age the variation of shrinkage is less sensitive to the fibers content, such as the curves shown in Fig. 9 are less descending. In the long term, the effect of fibers is more positive and the variation of shrinkage is represented by curves down showing a significant decrease compared to concrete without fiber. This phenomenon can be explained by the rubbing that exists along the contact boundary between the fibers and the matrix. The high fibers content increases the contact area between the fibers and the matrix; the adherence can reduce the deformation of the Drying shrinkage.

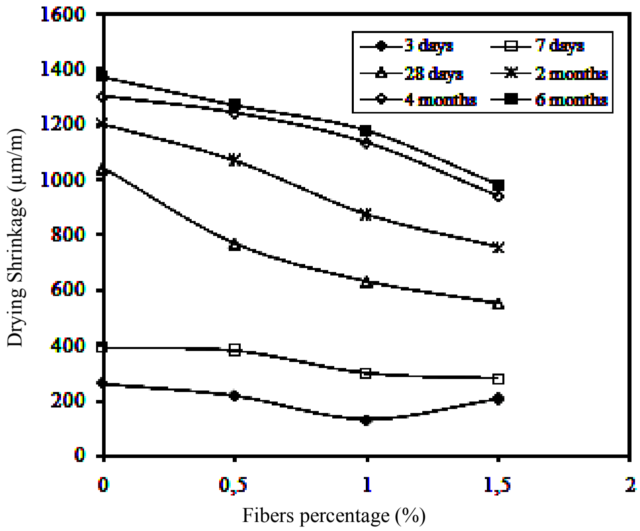

Fig. 9 Drying shrinkage depending on the fibers content

IV. Conclusion

This study aims to quantify the effect of addition of steel fibers on mechanical properties of concrete, including compressive strength and flexural strength, and also there effect on deformation of concrete under drying shrinkage. After work performed we can conclude that:

- The workability of concrete is negatively influenced by the introduction of metal fibers, and the dosage of these fibers plays a more important role.
- The flexural strength of the concrete increases versus time, and the addition of steel fibers cause a significant improvement in the resistance which value double in the presence of 1.5% fiber.
- Compressive strength on prismatic specimens evolves versus time whatever the dosage of fibers used. This gain depends on the concentration and geometry of these fibers.
- Drying shrinkage decreases with increases in proportion of fibers dosage. This decrease is in the order of 26, 39

and 46% compared to concrete without fibers at 28 days, respectively, for the proportions of 0.5, 1 and 1.5% fibers volume. In the long term, the effect of fibers is more positive than the early age and the shrinkage is reduced by the presence of fibers.

So we can say that the metal fibers improve the mechanical behavior, and do not eliminate the shrinkage but help to it controlled, the use of steel fibers in concrete provides a significant improvement to shrinkage which allows us to say that the presence of these types of fibers in construction materials will reduce the damage.

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