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Effect of Chopped Fibres Addition on the Behaviour of a New Textile Reinforced Concrete Under Flexural Loading

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ABSTRACT

Advances in the construction manufacturing have led to the development of innovative structural systems to reduce the structures weight. Accordingly, Textile Reinforced Concrete (TRC) as a technology that uses fibre reinforcement grids for strengthen concrete structures, notably glass and carbon fibres was introduced. Indeed, researchers have integrated these fibres within the concrete matrix to reduce cracking and improve flexibility. Compared to traditional concrete reinforcement methods, TRC offers several advantages, notably high corrosion resistance and flexibility. In this respect, the present work presents the results of an experimental study on the behaviour of high - performance mortar specimens reinforced by glass fibre grids. The effect of short glass fibres addition with 0.25, 0.5 and 0.75% was deeply studied under axial compression and four-point bending. The obtained results showed that the addition of short fibres within the mortar significantly improves the performances of the TRC, especially the structural ductility.

Keywords: Textile Reinforced Concrete, Glass fibre, Choppedfibres, Bending, Compression.

I. INTRODUCTION

The use of textile reinforcement in concrete structures is a promising solution for reducing the ecological impact of the construction industry [1] . By replacing conventional steel-bars, textile reinforcement offers numerous advantages. In fact, textile reinforcement enables a significant reduction of concrete consumption by designed thin-TRC members. In addition, textile reinforcements offer great design and flexibility[2,3], as they can be easily shaped and molded to manufacture complex geometries, enabling the design of innovative and efficient structures [4-6].The corrosion resistance of textile reinforcements means that minimal concrete cover is required for steel reinforcement. This reduces the thickness of concrete elements and ensure a long-life of the structure, resulting in lower maintenance and repair costs over time. Overall, the incorporation of textile reinforcements in lightweight concrete structures represents a promising approach to minimize the construction industry's ecological footprint, by reducing material consumption, carbon emissions,and improving durability [7]

Within the framework of sustainable development, many of researchers have studied the effect of reducing the cement amount in the matrix of Fibre Reinforced Concrete (FRC). The most investigations aimed for a sand/blender ratio of around 0.36 [1,8].By reducing the cement content, the environmental impact of the cement industry which is responsible for significant carbon dioxide (CO2) emissions [1,9]was minimized.

Furthermore, the use of chopped fibres in textile-reinforced concrete provides several advantages. Also, enhances the mechanical properties of concrete, improves crack control, increases durability, and affects the workability of fresh concrete[10,11].The properties of the fibres, such as material type, length, diameter, and distribution, can influence the performance of the textile-reinforced concrete. However, it is essential to conduct specific studies and tests to optimize the reinforcement for practical applications. In addition, construction practices may vary based on local standards and regulations[12-14].

Accordingly, this study introduces an experimental investigation about the influence of chopped glass fibres addition combined with an increased sand/binder ratio to 2.2. A textile-reinforced concrete samples were investigated four-point bending by incorporating glass chopped fibres with various amounts. Theprocedure objective was to evaluate the mechanical behaviour and flexural performance of designed samples. Indeed, different percentages of chopped fibres were incorporated within the concrete mixture according to a one-layer textile reinforced concrete to enhance strength and ductility. Specimens were then tested under four-point bending to measure the load-deflection response and to determine the flexural capacity of the textile reinforced concrete members. In addition, the study aimed to analyze the influence of fibre content on the crack formation, load-carrying capacity, and overall structural behaviour of textile-reinforced concrete.Theobtained results from this experimental investigation provide valuable insights about the performance and potential applications of textile-reinforced concrete as structural elements subjected to flexural loading.

I. EXPERIMENTAL METHODS AND MATERIALS

A total of15 plates with $400 \times 100 \times 20\ mm^3$dimensions and 12 cube specimens with $50x50x50\ mm^3$ were casted and tested. Tables 1 and 2 illustrate the designation and composition of each specimen. It is significant to notice that three identical specimens were fabricated for each sample set. The plates were subjected to four-point bending test, while the cubes were tested under compression, as shown inFig. 5. The experiments were carried out according to the works of [15-20]

Fibre reinforcement

A commercial glass textile was employed to reinforce the specimens. The fibre yarns arranged according to two orthogonal directions.Fig. 1 and Table 1 depict the geometric and mechanical characteristics of the used glass textile, respectively. Regarding the chopped fibres, 6 mm length were used. The volume fractions of added chopped fibres to concrete mixtures were 0. 5%, 0.75%, and 1%.

a *b*

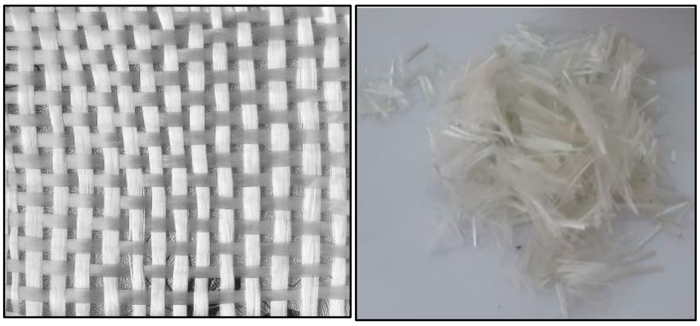

Figure 1. Used glass fibres: a) glass textile,b) glass chopped fibres

TABLE 1. MECHANICAL PROPERTIES OF MONOFILAMENT GLASS FIBRE REINFORCEMENT

Parameter	**Value**
Tensile strength (Mpa)	3100
Young's modulus (GPa)	72
Elongation at failure (%)	4.5

Mix composition and specimenpreparation

The used mortar for the preparation of the samples is based on river sand with a maximum grain size of 1.25 mm, the sand characteristics are given in Table 2. The used cement designated as MATINE is a Portland cement, class 42.5, and subclass B, sourced from the LAFRAGE cement plant in Algiers. MEDAFLOW30 superplasticizer and silica fume provided GRANITEX company (Algeria) were also used. Table 2 presents the composition of the high-performance mortar used to prepare the TRC plates, while, Table 3 provides the designation and composition of the designed specimens.

After determining the proportions of each component, the dry materials are introduced within the mixer. The mixer is started to homogenize the dry mixture for 2 minutes until a unified color is obtained. After that, an amount of liquid mixture containing water and superplasticizerwas added and mixed for 2 minutes. Adding the remaining the liquid mixture. Finally, the fibres were progressively incorporated to allow a homogeneousmixture. The compressive and flexural test specimens were kept in the molds and covered with a plastic sheet for 24 h. After that, the specimens were demolded and kept in water until the day before the test. After 28 days, the specimens are removed from water and placed in the open air under laboratory conditions to acquire the normal state of humidity.

TABLE 2. PHYSICAL PROPERTIES OF USED SAND

Mechanical properties	**True density**	**Apparent density**	**Sand equivalent (%)**	**Fineness modulus**
River sand	2.66	1.66	92.22	2.93

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TABLE 3. THE MIX DESIGN PROPORTIONS OF USED MORTAR

Material	Cement	Silica fume	Sand	Water	Super plasticizer	w/b	s/b
Amount (kg/m3)	600	30	1400	200	8	0,31	2,53

TABLE 4. DESIGNATION OF ALL DESIGNED AND TESTED SPECIMENS

Designation	Glass textile	Chopped fibres %
RW	-	-
WCF	1	-
CF0.5	1	0,5
CF0.75	1	0,75
CF1	1	1

Figure 2. Specimens confection and conservation

Flexural and compressive tests instrumentation

In order to evaluate the contribution of fibres reinforcement before and after cracking, four-point bending tests were conducted as shown in Fig. 3 a.The load and deflection were automatically measured at the application area of the load using the software integrated in the used ZWICK/ROELL Z250 machine. The samples were loaded with a constant loading speed rate of 0.5KN/S and each sample group contained three specimens. In addition, the maximum flexural tensile strength, was determined using Equation 1, where P^{max}*is the maximum recorded load, L is the span length (400 mm), b (100 mm) and h (20 mm) are the width and thickness of the cross-section, respectively.*

$$\sigma_t = \frac{p^{max}L}{bh^2} \qquad (1)$$

Furthermore, compressive tests were realized on concrete cubes according to BS EN 12390-3: 2019. Three 50 × 50 × 50 mm3cubes were confectioned and tested for each mixture. The tests were performed under force-controlled conditions at a rate of 1.5 KN/s at 28-day age, as shown in Fig. 3 b.

a *b*

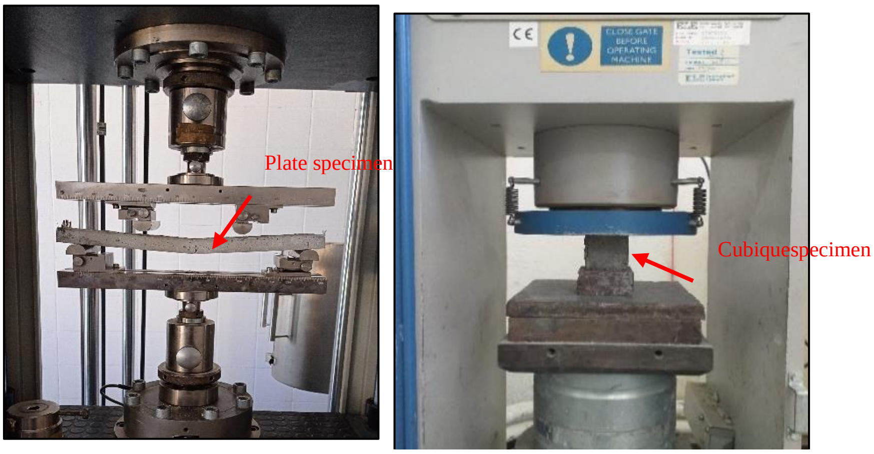

Figure 3. Specimens under the test machines
a) Flexural test, b) Compression test.

II. RESULTS AND DISCUSSION

Table 4 recapitalizes the obtained results in terms of first crack load and maximum load with their corresponding deflections, as well as the flexural and compression strengths for the different specimens. In addition, Table 5 gives the gains recorded by the use of chopped fibre in different parameters. Indeed, the addition of chopped glass-fibres improves the overall behaviour of the specimens, particularly in the post-cracking phase in terms of increased strength and flexibility.

TABLE 5. RESULTS OF FLEXURAL AND COMPRESSION TESTS

	First crack load (N)	First crack load deflection (mm)	Maximum load (N)	Maximum deflection (mm)	Flexural strength (Mpa)	Compressive strength (Mpa)
WR	1 184.32	0.61	1 184.32	0.61	11.84	35.13
WCF	753.71	0.73	998.85	3.54	9.99	-
CF0.5	1 053.71	0.99	1 053.71	5.76	10.54	36.21
CF0.75	1 325.41	0.93	1 325.41	6.86	13.25	38.05
CF1	1 414.24	1.38	1562	8.10	15.62	44.67

Figure 4 shows the comparison of the 28-day compressive strengths of the various tested specimens. The results conclusively demonstrate that the addition of short fibres to the mortar leads to a clear improvement of the compressive strength, particularly in the case of specimen FC1, for which a gain of 27.16 % was obtained .

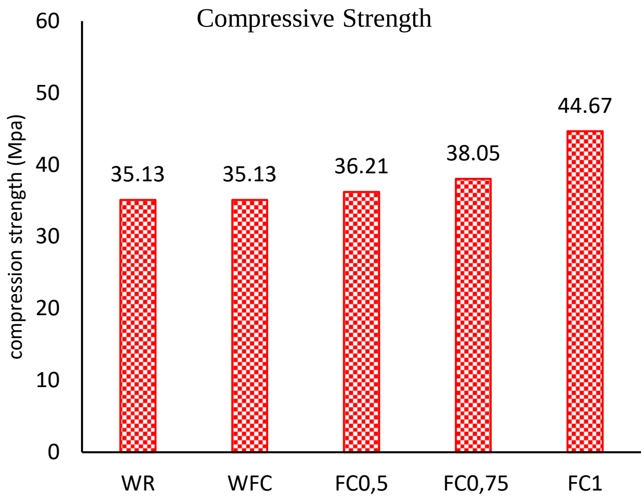

Figure4. Histograms of 28-day compressive strengths.

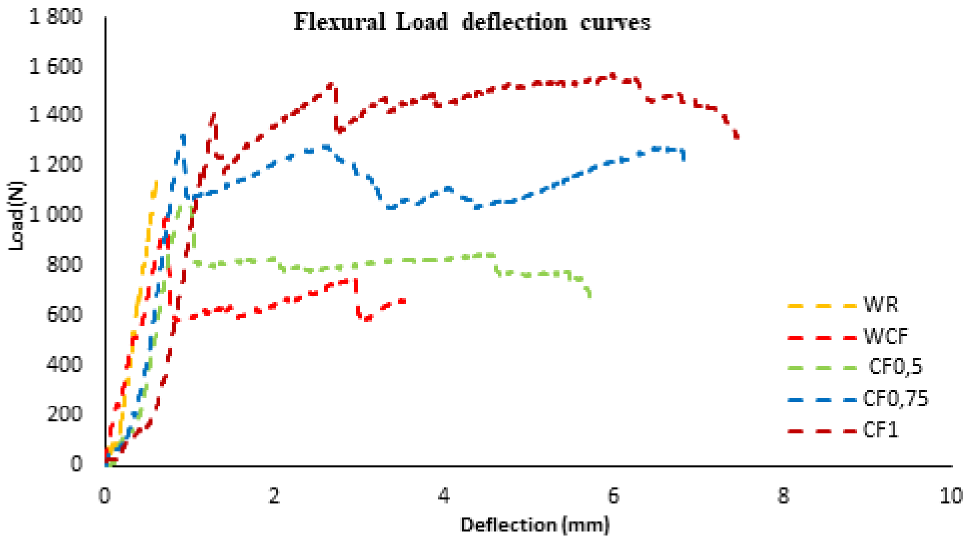

Figure. 5. Flexural load versus midspan deflection curves of tested samples.

A confrontation between the obtained different load -deflection curvesunder flexural test is presented in Fig.5. It can be observed that the inclusion ofchopped glass-fibreswithin the textile-reinforced concrete (FC0.5, FC0.75, and FC1) improves the mechanical behaviour and material performances. Indeed, the presence of chopped glass-fibres allows to preventthe appearance of the first cracks, as indicated by the higher loads and first crack deflectionscompared to the sample without chopped fibres (WCF).A gain in terms of first crack load of 89.22% was obtained for specimen FC1. In addition, the increasing of the chopped-fibres amount improves the deformability of the TRC.

Figure 6 shows the ultimate bending load and stress values. The use of 1% of chopped glass-fibres improved the maximum load and bending strength to 1562 N and 15.62 Mpa, respectively. The values with the other percentages (FC0.5, FC0.75) achieved also better flexural strengths compared to the sample without fibres (WFC). In fact, the gains in terms of maximum load and flexural strength increase with increasing the amount of chopped fibres.

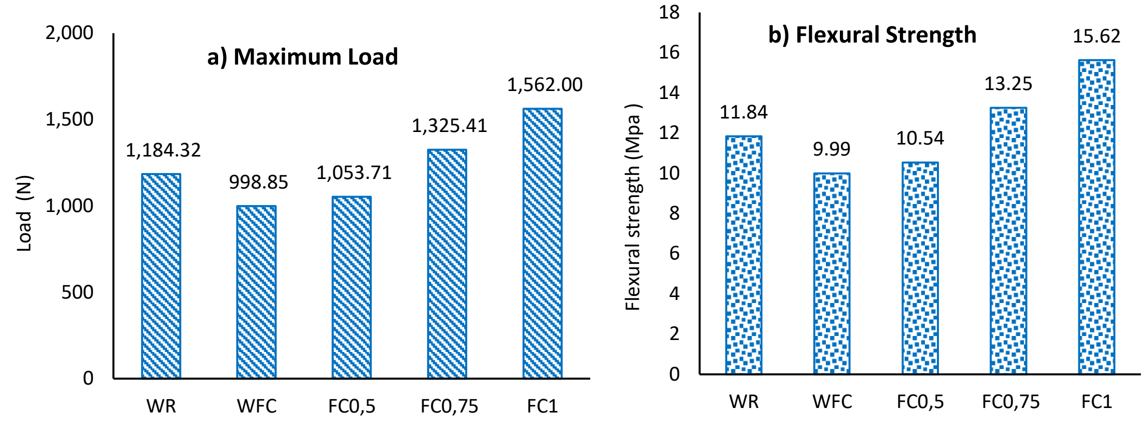

Figure 6. Histograms of maximum loads and flexural strength of tested TRC plates.

Figure 7 compares the first crack load and maximum deflections obtained for the different spicimens subjected to four-point bending. It can be seen that the use of chopped glass-fibres significantly improves the deformability of the mortar matrix and retards the development of the first cracks. Acorndingly, an improvement of maximum deflection was recorded with anobtained gain of around 128 % for the FC1 group.

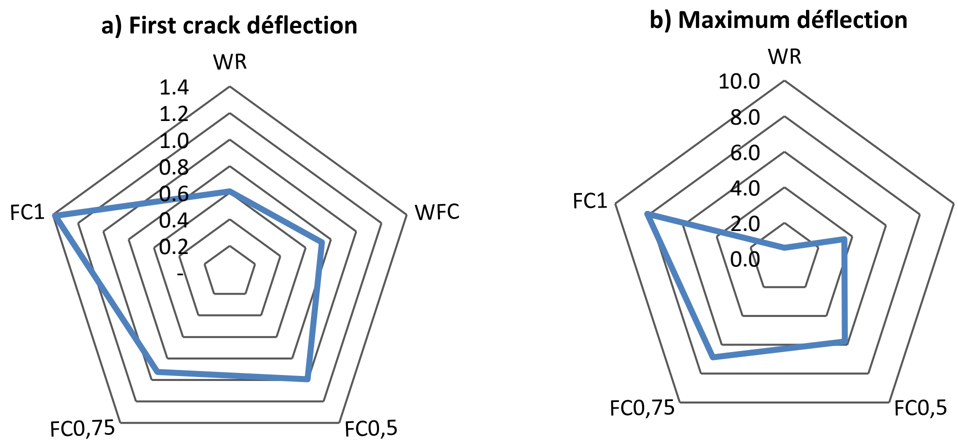

Figure7. Fexural test results of TRC plates in terms of deflection radars:
a) First crack deflections; b) Maximum deflections

TABLE. 6. RECAPITULATION OF ALL OBTAINED GAINS

Samples	Gains (%)			
	First crack deflection	Maximum load	Maximum deflection	Compression strength
FC0.5	36.18	5.49	62.81	3.07
FC0.75	26.77	32.69	93.82	8.31
FC1	89.22	56.38	128.89	27.16

D. Failure modes

Theprimary rupture mechanism of tested samples under bending is summarized in Fig.8. Control specimens, namely: RW and DW group,without textile reinforcement behaved brittle with a large crack in the whole width of the specimens. The strengthened specimens with a one-layer glass textile and choppedfibres are all characterized by the development of several cracks, due to the high deformability provided by the textile and the chopped fibres.

Figure 8. Rupture mechanism of designed samples under flexural loading.

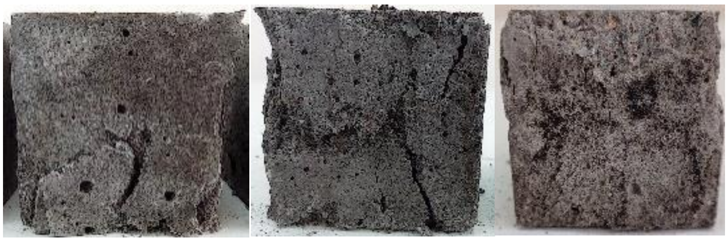

Figure 9. Rupture mechanism of designed samples under axial compression

III. CONCLUSION

In this study, the impact of incorporating chopped glass-fibres to improve the structural performance of a new glass textile-reinforced concrete with a 2.2 s/b ratio was investigated. A series of *400x100x 20 mm*^{3}specimens and *50 × 50 × 50 mm*^{3}cubes were confectioned and tested under four-point bending and compression respectively. The mechanical behaviour of the TRC was evaluated by analyzing the load-deformation curves of the plates and the 28-day compressive strength.

As key outcomes, the addition of chopped glass-fibres within textile-reinforced concrete considerably improved the performances, namely under bending. Indeed, the fibres acted as dispersed reinforcements in the concrete matrix, impeding crack propagation and improving the material's strength. This enabled the concrete to better bending resistance and compressive strength. These results indicated that the incorporation of chopped glass-fibres within textile-reinforced concrete improves the overall structural performance.

The used 2.2 s/b ratio in this study produced very satisfactory results, highlighting the use of a high quantity of sand in relation to cement one, which implies a reduction of used cement. This could be an important strategy for improving the performance of materials in various construction applications, while at the same time reducing the use of cement, the production of which has adverse effects on the environment. Finally, the deigned specimens provide a promising material for applications requiring high bending resistance.

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