Revue des Composites et des Matériaux Avancés-Journal of Composite and Advanced Materials
Vol. 36, No. 4, August, 2026, pp. 679-685
Journal homepage: http://iieta.org/journals/rcma

Performance of Concrete Reinforced with Recycled Drink Can Fibers

Chiraz Kechkar[1*], Ghania Nigri[1], Fatima Zohra Benamara[1], Houria Hebhoub[2], Ferriel Harrat[3]

[1] Laboratory of Civil Engineering and Hydraulic (LGCH), University 8 May 1945, Guelma 24000, Algeria
[2] Materials, Geotechnics, Housing and Urban Planning Laboratory (LMGHU), University 20 August 1955, Skikda 21000, Algeria
[3] Department of Civil Engineering and Hydraulic, University 8 May 1945, Guelma 24000, Algeria

Corresponding Author Email: kechkar.chiraz@univ-guelma.dz

https://doi.org/10.18280/rcma.360401

Received: 8 April 2026
Revised: 14 July 2026
Accepted: 28 July 2026
Available online: 31 August 2026

Keywords:
concrete, metal fiber, mechanical properties, physical properties, solid waste, drink cans

ABSTRACT

This study focuses on the recycling and recovery of abundant solid waste, such as metal fibers derived from drink cans, for use in concrete production. It investigates the effects of incorporating these fibers on the concrete's performance. Therefore, concrete specimens were produced with varying percentages of fibers, ranging from 1% to 3% by mass of cement. Their properties were compared to those of an ordinary concrete (OC) mix in terms of workability, dry density, water absorption, ultrasonic pulse velocity (UPV), compressive strength, flexural strength and splitting tensile strength. The results showed that incorporating drink can fibers reduced workability, hardened density, UPV, water absorption and compressive strength. However, it enhanced flexural strength and splitting tensile strength. Up to a fiber content of 2%, the results remained acceptable, with an 8.6% reduction in 28-day compressive strength, and improvements in splitting tensile strength and flexural strength of 13.7% and 18.98%, respectively.

1. INTRODUCTION

Buildings and civil engineering structures are generally made of concrete. Its implementation requires few resources; its plasticity allows for multiple shapes, good compressive strength and increased long-term durability [1-3].

Despite all its advantages, concrete remains a brittle material with low tensile strength. The main purpose of reinforcing it with fibers is to improve its tensile behaviour in order to delay, limit or prevent quasi-brittle fracture [4, 5].

Fiber-reinforced concrete (FRC) is a building material that has been rapidly developing since the 1990s. Several research projects have highlighted the advantages of this composite material, such as increased post-cracking strength, ductility and durability [6, 7].

Among the different fiber types, metal fibers are the most widely adopted due to their capacity to substantially enhance the mechanical performance of concrete [8].

However, the main drawback of FRC remains the high cost of fibers, which can sometimes outweigh immediate benefits. Consequently, alternative materials based on recycled or reused fibers appear as a promising solution to mitigate this limitation [9].

On the other hand, the accumulation of non-degradable waste, which is becoming increasingly uncontrollable and occupying a significant amount of public space [10, 11], has highlighted the recycling of this waste for several uses, namely applications in the construction industry, which both reduce manufacturing costs and improve the performance of cementitious composites, not to mention protecting the environment [12, 13].

Furthermore, metals are the most recycled materials in the world. Unlike other materials, and thanks to current technology, they are relatively easy and inexpensive to separate and reintroduce into the manufacturing cycle. Among the most popular recyclable metals are aluminum and steel, which can be reintroduced into the cycle over and over again without losing their properties [14, 15].

Among metallic waste streams, discarded aluminium beverage cans represent a critical environmental concern due to their accumulation in ecosystems. Because aluminium is highly resistant to natural degradation, these cans persist in the environment for extensive periods. Repurposing these cans as concrete reinforcement provides an effective strategy to reduce their ecological impact and advance sustainable waste management.

Several research studies have been conducted on the reuse of cans in civil engineering, particularly as fiber in construction materials such as concrete.

Ekah and Emeruwa [5] studied the effect of adding recycled fibers from beverage cans to concrete at percentages ranging from 1% to 4% of the cement mass. They found an improvement in flexural strength and splitting tensile strength. However, they noted a decrease in compressive strength.

Another study conducted by Ilya and Cheow Chea [3] added fibers from beverage cans at percentages of 1% and 2% of the cement mass. They noted that at a rate of 1%, the concrete's mechanical properties improved. Beyond that, all mechanical properties decreased.

Similarly, a study by Khai and Ha [16] on the addition of 2% recycled can fibers reported a decrease in compressive strength (-22%) as well as in the Static modulus of elasticity (-11%).

However, in a study conducted by Gherdaoui et al. [17], they showed that adding fibers from drink cans at percentages of 0%, 0.5%, 1%, 1.5%, 2% and 2.5% increases compressive strength, as well as flexural strength. Furthermore, it contributed to reducing crack propagation.

Similarly, Sambrano and Estores [18] investigated the influence of the percentage and size of soft drink can fibers on the compressive strength of concrete hollow blocks. Fibers were prepared in three sizes: 15 mm, 20 mm, and 25 mm. For each size, fibers were added at 2%, 2.5%, and 3% of the cement mass. Compressive strength increased with fiber content, regardless of size. But the highest compressive strength was attained by the mixture (3%, 25 mm).

Based on previous studies, most of which have focused on mechanical properties, researchers agree that fibers extracted from drink cans improve the flexural and tensile strength of concrete. However, the results regarding compressive strength are conflicting. Furthermore, research examining other properties, such as water absorption and ultrasonic pulse velocity (UPV), remains scarce.

In this context, this work aims to evaluate the performance of concrete reinforced with metal fibers derived from an abundant waste product, specifically recovered from used beverage cans.

2. MATERIALS AND METHODS

2.1 Materials

The materials used in this study are: CEM II/A-L42.5N Portland cement from the HADJAR-SOUD cement factory. Its main physical properties are: bulk density 1.09 g/cm³, density 3.11 and Blaine specific surface area 3371 cm^2/g.

Rolled sand class 0/3 mm from the Tebessa region with a fineness modulus of 2.28 and a density of 2.56, and two types of crushed limestone gravel, classes 3/8 mm and 5/15 mm, with a density of 2.72 and a Los Angeles coefficient of 34%. The particle size distribution of the utilized aggregates is shown in Figure 1.

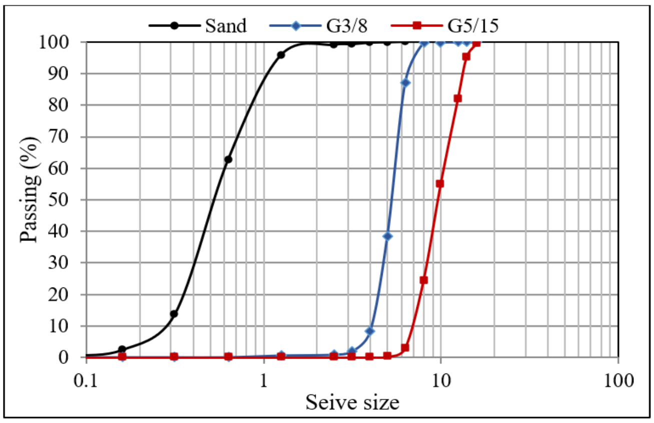

Figure 1. Particle size distribution of the aggregates used

The fibers used are metal fibers obtained from recycled drink cans (Figure 2). This waste was collected from restaurants, washed with water, dried in the open air, and then cut with shears into straight fibers 4 cm long, 4 mm wide to obtain an aspect ratio of 10 (Figure 3). The elaborated fibers have a thickness of 0.1 mm, a bulk density of 0.08 g/cm³, and a density of 1.67 g/cm^3. No prior treatment was applied to the fibers.

Figure 2. Drink cans

Figure 3. Drink can fibers

2.2 Experimental methodology

In this study, an ordinary concrete (OC) mix design was aimed for 30 MPa at 28 days and plastic workability (Abrams cone slump of 7 cm). The maximum aggregate size used is D_{max} = 15 mm, and the cement dosage is set at 400 kg/m³.

Table 1 presents the mix proportions for the concrete formulations. Four mixtures were prepared as follows:

•OC: Ordinary concrete without any waste materials.

•FC1%, FC2%, and FC3%: Fiber-reinforced concrete containing 1%, 2% and 3% fibers by mass of cement.

Table 1. Mix proportions

	OC	FC1%	FC2%	FC3%
Cement (kg/m^3)	400	400	400	400
Gravel 5/15 (kg/m^3)	1048	1048	1048	1048
Gravel 3/8 (kg/m^3)	215	215	215	215
Sand (kg/m^3)	588	588	588	588
Water (L)	211	211	211	211
Fiber content (%)	0	1	2	3
Fibers (kg/m^3)	0	4	8	12
W/C	0.53	0.53	0.53	0.53

The mixing was performed using a concrete mixer. The process began with the introduction of sand and gravel, which were mixed dry for 2 minutes to ensure proper dispersion of the aggregates, followed by the addition of cement for an additional 1 minute. The mixing water was then incorporated for 2 minutes of wet mixing. Finally, the fibers were added, and mixing continued until a perfectly homogeneous concrete was obtained (Figure 4).

Figure 4. Drink cans fibers in concrete

The experimental program for the different concrete mixtures is presented in Table 2. Figures 5-8 illustrate the test setups for the Abrams cone slump, ultrasonic velocity, compression, and flexural strength tests, respectively.

Figure 5. Slump test

Figure 6. Ultrasonic velocity test

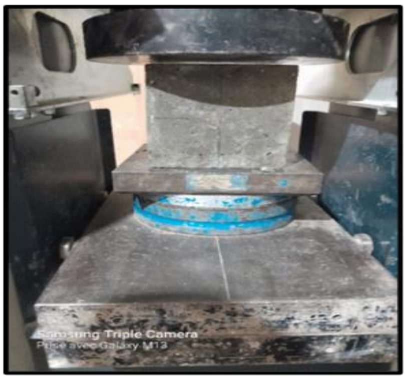

Figure 7. Compression strength measurement

Figure 8. Flexural strength measurement

Table 2. Experimental testing standards and parameters

Test	Standard	Specimen Dimensions (cm)	Number of Specimens	Testing Age (days)
Abrams cone slump	NF EN 12350-2 [19]			
Dry density	NF EN 12390-7 [20]	10 × 10 × 10	3	
Water absorption test	NBN B 15-215:1989 [21]	10 × 10 × 10	3	
Ultrasonic velocity	NF EN 12504-4 [22]	15 × 15 × 15	3	7, 14 and 28
Compression strength	NF EN 12390-3 [23]	10 × 10 × 10	3	7, 14 and 28
Flexural strength	NF EN 12390-5 [24]	7 × 7 × 28	3	7, 14 and 28
Splitting tensile strength	NF EN 12390-6 [25]	15 × 15 × 15	3	7, 14 and 28

3. RESULTS AND DISCUSSION

3.1 Workability

According to the results presented in Figure 9, the slump decreases as the fiber dosage increases. In fact, it decreases from 8 cm for OC to 4 cm, 3 cm and 2.5 cm for fiber contents of 1%, 2%, and 3%, respectively. Therefore, compared to OC, there is a decrease in slump of 50%, 62.5% and 68.75% for FC1%, FC2% and FC3%, respectively. This decrease can be attributed to the intertwining of the fibers in the concrete mixture and their non-uniform distribution, which creates internal friction between the concrete matrix and the fibers [19]. These results confirm those of a previous study [26].

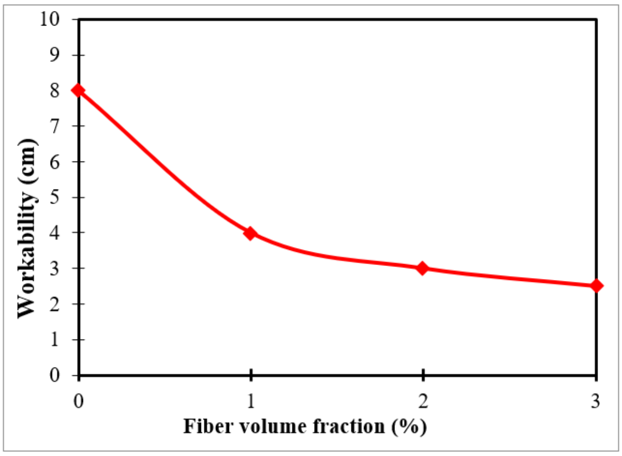

Figure 9. Workability variation with different fiber percentages

3.2 Dry density

The dry density test shown in Figure 10 indicates that adding fiber reduces the density of hardened concrete. This decrease increases with the percentage of fiber. It goes from 2361 kg/m^3 for OC to 2282 kg/m^3, 2274 kg/m^3 and 2266 kg/m^3. The decrease varies between 3.3 and 4% compared to OC. This is due to the advantage of aluminium in reducing the density of mixtures [27]. This result is consistent with those reported by previous studies [17, 27].

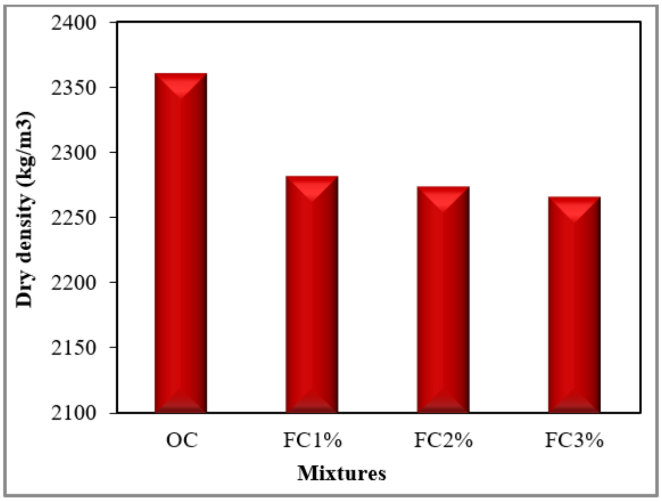

Figure 10. Dry density variation with different fiber percentages

3.3 Water absorption

The results for water absorption are shown in Figure 11. It can be seen that the water absorption of FRC is lower than that of OC, and it decreases with the increase in fiber percentage.

Water absorption decreases from 6.61 ± 0.32% for the OC to 6.39 ± 0.48%, 6.29 ± 0.52%, and 4.71 ± 0.27% for the FRC FC1%, FC2%, and FC3%, respectively. This represents a reduction in water absorption of 3.3%, 5.3%, and 28.7% compared to the OC. The reduction in water absorption can be attributed to the reinforcement of the internal structure of the hardened concrete. The fibers increase the tortuosity of the pore network and potentially create isolated pores, thus restricting capillary suction and reducing water absorption [28].

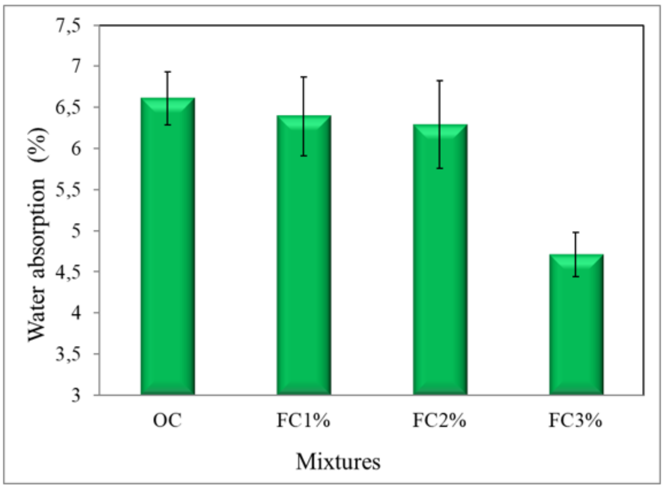

Figure 11. Water absorption of different mixtures

3.4 Ultrasonic pulse velocity

The UPV of the different concrete samples was measured after 7, 14, and 28 days of water storage. The results are presented in Figure 12. Based on the results, it can be said that the velocities obtained for the different formulations indicate that the concrete samples are of good quality (V > 3500 m/s).

It can also be seen that the addition of drink can fibers reduces the UPV of the concrete for all ages studied. This decrease increases with the increase in the percentage of fibers. For example, at 28 days of age, this decrease is around 4.1%, 4.8% and 8% for FC1%, FC2% and FC3%, respectively. This trend may be attributed to the reduction in density previously observed [29] and to the decreased workability, which resulted in a higher volume of entrapped air and a less compact matrix.

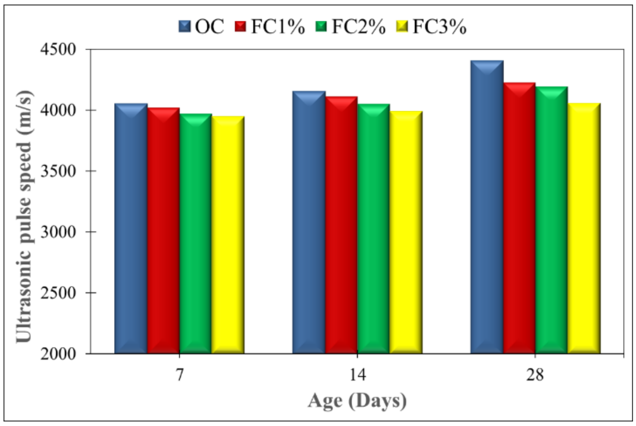

Figure 12. Variation in ultrasonic pulse speed as a function of concrete mixture age

3.5 Compressive strength

As illustrated in Figure 13, the addition of fibers from drink cans is accompanied by a reduction in compressive strength. This decrease increases with the increase in fiber percentage. After 28 days of storage, OC had a strength of 32.79 MPa, compared to compressive strengths of 31.45 MPa, 29.97 MPa and 29.02 MPa for the three FRCs, FC1%, FC2% and FC3%, respectively. The differences observed are therefore 4.1%, 8.6% and 11.5%, respectively. This decrease can be explained by the low adhesion between the fibers used and the cement paste, due to their smooth surfaces [5, 29] and to the lower workability, which led to a higher content of entrapped air and a less compact matrix. In addition, the reduction in compressive strength could be attributed to the possibility of a reaction between the aluminium waste fibers and the calcium hydroxide ($Ca(OH)_2$), formed by Portland cement hydration [27], which releases hydrogen gas, leading to increased porosity and reduced strength [28, 30]. Despite the decrease in strength, the values remain acceptable, close to the required strength (30 MPa). Similar results were found by studies [5, 31].

According to Figure 14, it is observed that the relationship between compressive strength and ultrasonic velocity takes the form of an approximately non-linear increasing curve. This result has been confirmed by several researchers [32, 33].

From the results obtained, the following relationship between compressive strength (f_c in MPa) and ultrasonic velocity (V in m/s) was derived, with $R^2 = 0.81$:

$$f_c(MPa) = -0.00004V^2 + 0.3962V - 846.5 \quad (1)$$

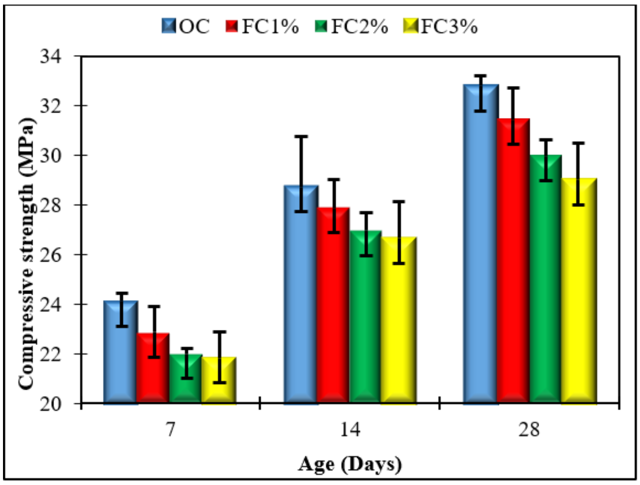

Figure 13. Compressive strength as a function of concrete age

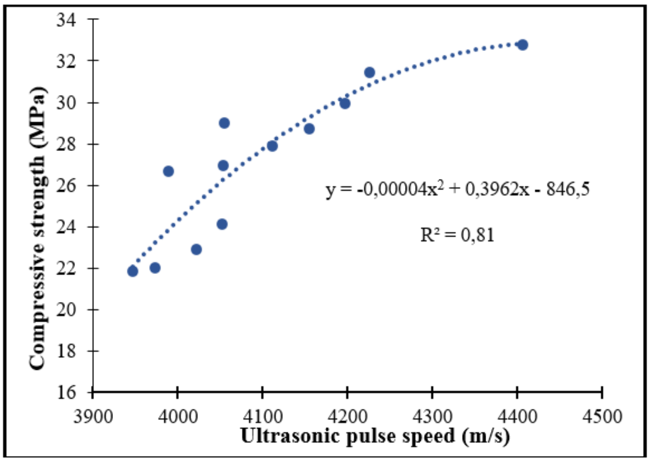

Figure 14. Relationship between compressive strength and ultrasonic pulse speed for concrete with drink can fibers

3.6 Splitting tensile strength

According to Figure 15, it is observed that for the different ages studied, the splitting tensile strength continues to increase for all four types of concrete studied. It can also be seen that FRC has a higher splitting tensile strength than OC.

For example, the 28-day splitting tensile strength of OC is 3.13 MPa, compared to 3.52 MPa, 3.56 MPa and 3.45 MPa for FC1%, FC2% and FC3%. This represents an increase of 12.5%, 13.7% and 10.2% for FC1%, FC2% and FC3% respectively. This increase is attributed to the fiber bridging mechanism. As the splitting load induces lateral tensile stresses, the fibers intercept advancing cracks, preventing their rapid propagation. However, the splitting tensile strength of FC3% was lower than those of FC1% and FC2%. This decline may be linked to the high fiber concentration, which adversely affects the interfacial adhesion between the aggregates and the matrix [3]. The same result was observed by Wijatmiko et al. [27].

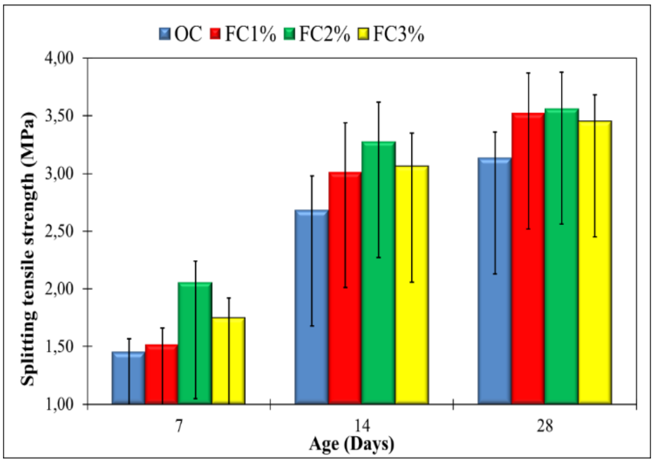

Figure 15. Variation in splitting tensile strength as a function of concrete mixture age

3.7 Flexural strength

The results for flexural tensile strength are presented in Figure 16. The same observation can be made as for splitting tensile strength: an increase in the flexural tensile strength of FRC as the fiber content increases, up to a content of 2% compared to OC.

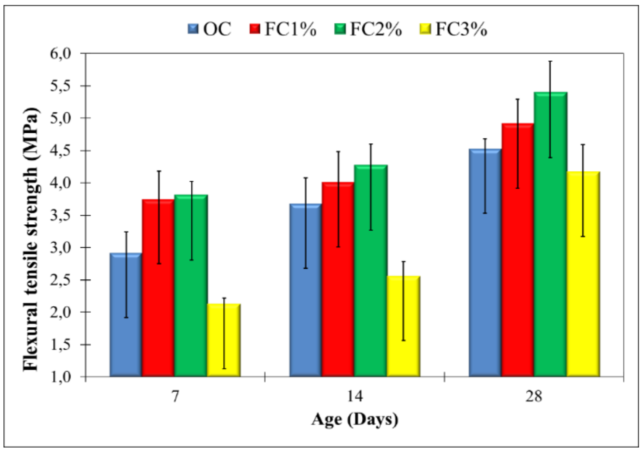

Figure 16. Flexural strength as a function of concrete age

For example, the 28-day flexural tensile strength of OC is 4.53 MPa, compared to 4.92 MPa and 5.39 MPa for FC1% and FC2%, respectively. Thus, there is an increase of 8.6% and 18.98% for FC1% and FC2% concrete, respectively. However, the strength begins to decrease at a fiber content of 3%. The same trend was observed by Wijatmiko et al. [27].

3.8 Mode of failure

Figure 17 shows the failure modes of the test specimens subjected to flexural testing. OC specimens exhibited brittle failure, splitting completely into two pieces upon reaching peak load. In contrast, FRC specimens demonstrated a ductile failure mode characterized by plastic deformation, remaining intact with visible cracking rather than total separation. Furthermore, crack widths decreased progressively with increasing fiber content up to 2%, whereas specimens with 3% fiber displayed wider and more concentrated cracking. So, the fibers transform the failure mode from brittle to more ductile behaviour, allowing the specimens to sustain higher tensile loads compared to the OC. Similar results were found by Gherdaoui et al. [17].

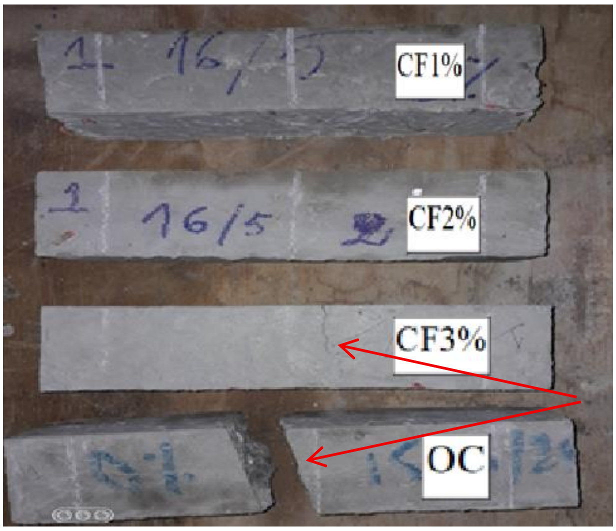

Figure 17. Flexural tensile failure behaviour of the 04 test specimens

4. CONCLUSIONS

In this experimental study, the performance of concrete reinforced with metallic fibers derived from used drink cans was examined. Based on the results obtained, the following conclusions can be drawn:

•The incorporation of fibers led to reductions in workability, dry density, UPV, and water absorption.

•Compressive strength decreased with increasing fiber content, dropping from 32.79 MPa for the OC to 31.35 MPa at 1%, 29.34 MPa at 2% and 24.32 MPa at 3%. However, dosages up to 2% retain an acceptable compressive strength (29.34 MPa), remaining close to the target design strength of 30 MPa.

•A non-linear relationship between UPV and compressive strength was established for the concrete mixes studied, providing a satisfactory approximation, with a coefficient of determination (R^2) of 0.81.

•Splitting tensile strength increased with fiber addition, with an optimal percentage of 2% yielding an improvement of 13.7%.

•The addition of fibers up to 2% increases flexural tensile strength by 18.98%.

•A fiber content of 2% is recommended, as it offers the optimal balance between acceptable compressive strength retention and maximum improvements in splitting tensile and flexural strengths.

To build upon these findings, future work should:

•Explore fiber surface treatments (chemical or physical) to enhance the interfacial bond between the fibers and the matrix.

•Conduct microstructural analysis to investigate micro-level failure mechanisms and fiber-matrix adhesion.

•Evaluate long-term durability under harsh environmental conditions, including freeze-thaw cycles, moisture exposure, and chemical attack, to assess real-world applicability.

REFERENCES

[1] Mailar, G., Sreedhara, B.M., Manu, D.S., Hiremath, P., Jayakesh, K. (2016). Investigation of concrete produced using recycled aluminium dross for hot weather concreting conditions. Resource-Efficient Technologies, 2(2): 68-80. https://doi.org/10.1016/j.reffit.2016.06.006

[2] Aziz, H., Rishi, V. (2020). Review paper on concrete using soft drink aluminum cans fiber. International Research Journal of Engineering and Technology, 7: 348-352.

[3] Ilya, J., Cheow Chea, C. (2017). Mechanical behaviour of fibre reinforced concrete using soft–drink can. IOP Conference Series: Materials Science and Engineering, 271(1): 012079. https://doi.org/10.1088/1757-899X/271/1/012079

[4] Syamsir, A., Adnan, W., Anggraini, V., et al. (2020). Combine effect of soft drink tins and polypropylene fibres on mechanical properties of concrete. AIP Conference Proceedings, 2291(1): 020101. https://doi.org/10.1063/5.0022825

[5] Ekah, U.J., Emeruwa, C. (2020). Analysis of the mechanical properties of tin fibers on concrete. IOSR Journal of Mechanical and Civil Engineering, 17(1): 64-69. https://doi.org/10.9790/1684-1701046469

[6] Błaszczyński, T., Przybylska-Fałek, M. (2015). Steel fibre reinforced concrete as a structural material. Procedia Engineering, 122: 282-289. https://doi.org/10.1016/j.proeng.2015.10.037

[7] Salunkhe, S.P. (2018). Comparative study on fiber reinforced concrete and nominal concrete. International Journal for Scientific Research & Development, 5(10): 102-105.

[8] Kishore, K., Gupta, N. (2019). Experimental analysis on comparison of compressive strength prepared with steel tin cans and steel fibre. International Journal for Research in Applied Science & Engineering Technology, 7(4): 169-172. https://doi.org/10.22214/ijraset.2019.4030

[9] Lekoui, M.T., Kechkar, C., Hebhoub, H., Messaoudi, K., Alsayadi, H., Benhalilou, M.I. (2024). Study of the mechanical properties, durability, and microstructure of an ultra-high-performance fiber-reinforced concrete containing recycled fillers. Materials Science-Poland, 42(3): 1-16. https://doi.org/10.2478/msp-2024-0027

[10] Chiraz, K., Zohra, B.F., Ghania, N., Houria, H., Hamid, A., Karima, M. (2025). Utilization of eggshell powder as a green mortar material. Materials Science, 31(2): 241-247. https://doi.org/10.5755/j02.ms.37855

[11] Chiraz, K., Zohra, B.F., Ghania, N., Houria, H., Yacine, C., Belachia, M. (2021). Influence of NaOH treatment of

rubber aggregates on the durability properties of rubberized mortars. Selected Scientific Papers-Journal of Civil Engineering, 16(2): 189-201. https://doi.org/10.2478/sspjce-2021-0026
[12] Agwa, I., Abdelsalam, B., Hafez, R., Ftah, R. (2025). Behavior of eco friendly concrete reinforced with hybrid recycled fibers. Sustainable Structures, 5(1): 000064. https://doi.org/10.54113/j.sust.2025.000064
[13] Zhang, G., Ding, Z., Zhang, R., et al. (2022). Combined utilization of construction and demolition waste and propylene fiber in cement-stabilized soil. Buildings, 12(3): 350. https://doi.org/10.3390/buildings12030350
[14] Hafez, R.D.A., Ftah, R.O.A.A. (2026). Utilization of waste aluminum fiber as a new fiber in high-strength concrete (HSC). Journal of Umm Al-Qura University for Engineering and Architecture. https://doi.org/10.1007/s43995-026-00295-5
[15] Hekro, M.R., Mangi, S.A., Phul, W.H. (2024). Effect of aluminium fiber on the strength property of Concrete. Neutron, 23(2): 5-9. https://doi.org/10.29138/neutron.v23i02.204
[16] Khai, L.T.Q., Ha, D.N.N. (2025). Recycled aluminum can fibers for concrete reinforcement: Standardized testing of compressive strength and static elastic modulus. Journal of Materials & Construction, 15(2): 31-35. https://doi.org/10.54772/jomc.v15i02.1179
[17] Gherdaoui, M., Maanser, A., Ali, M., et al. (2026). The effect of aluminium fibres recycled from drink cans on the characteristics of mortar. Canadian Metallurgical Quarterly, 1-13. https://doi.org/10.1080/00084433.2026.2664385
[18] Sambrano, J.P., Estores, G.B. (2022). Optimization of compressive strength of wasted soft drink can fiber non-load bearing concrete hollow blocks. GEOMATE Journal, 22(94): 135-142. https://geomatejournal.com/geomate/article/view/8.
[19] NF EN 12350-2. (2019). Testing fresh concrete–Part 2: Slump test. AFNOR Editions. https://standards.iteh.ai/catalog/standards/cen/cf0e0511-2176-454c-948d-9e515f3a03f1/en-12350-2-2019.
[20] NF EN 12390-7. (2019). Tests on hardened concrete–Part 7: Density of hardened concrete. AFNOR Editions. https://www.boutique.afnor.org/fr-fr/norme/nf-en-123907/essais-pour-beton-durci-partie-7-masse-volumique-du-beton-durci/fa190568/83465.
[21] NBN B 15-215:1989. (1989). Tests on hardened concrete–Water absorption. Bureau for Standardization, Belgium. https://www.normadoc.com/products/nbn-b-15-215-1989-nbn348309-510578.
[22] NF EN 12504-4. (2005). Tests on concrete in structures–Part 4: Determination of the ultrasonic pulse speed. AFNOR editions. https://www.boutique.afnor.org/fr-fr/norme/nf-en-125044/essais-pour-beton-dans-les-structures-partie-4-determination-de-la-vitesse-/fa048399/24971.
[23] NF EN 12390-3. (2019). Tests on hardened concrete–Part 3: Compressive strength of test specimens. AFNOR Editions. https://www.boutique.afnor.org/fr-fr/norme/nf-en-123903/essais-pour-beton-durci-partie-3-resistance-a-la-compression-des-eprouvette/fa190566/83462.
[24] NF EN 12390-5. (2019). Tests on hardened concrete–Part 5: Flexural strength of test specimens. AFNOR Editions. https://www.boutique.afnor.org/fr-fr/norme/nf-en-123905/essais-pour-beton-durci-partie-5-resistance-a-la-flexion-des-eprouvettes/fa190567/83459.
[25] NF EN 12390-6. (2019). Tests on hardened concrete–Part 6: determination of splitting tensile strength of test specimens. AFNOR Editions. https://www.boutique.afnor.org/fr-fr/norme/nf-en-123906/essais-pour-beton-durci-partie-6-determination-de-la-resistance-en-traction/fa163501/39060.
[26] Elrefaei, A.E., Alsaadawi, M.M., Wagdy, W. (2023). Characteristics of high-strength concrete reinforced with steel fibers recovered from waste tires. Key Engineering Materials, 945: 145-156. https://doi.org/10.4028/p-d5v1nm
[27] Wijatmiko, I., Wibowo, A., Nainggolan, C.R. (2019). Strength characteristics of wasted soft drinks can as fiber reinforcement in lightweight concrete. GEOMATE Journal, 17(60): 31-36. https://geomatejournal.com/geomate/article/view/351.
[28] Alsayadi, H., Khaldi, N., Hebhoub, H., Rihia, C., Benhalilou, M.I., Messaoudi, K. (2024). The effect of recycled fibers on the mechanical properties and durability of sand concrete. Materials Science, 30(4): 513-525. https://doi.org/10.5755/j02.ms.36236
[29] Oan, A.F. (2019). An investigation on using pop-cans wastes fibers on the mechanical properties of concrete. International Journal of Latest Technology in Engineering, Management & Applied Science, 8(5): 74-78. https://www.ijltemas.in/DigitalLibrary/Vol.8Issue5/74-78.pdf.
[30] Gulmez, N. (2020). Roles of aluminium shavings and calcite on engineering properties of cement-based composites. Journal of Cleaner Production, 277: 124104. https://doi.org/10.1016/j.jclepro.2020.124104
[31] Qureshi, T., Ahmed, M. (2015). Waste metal for improving concrete performance and utilisation as an alternative of reinforcement bar. International Journal of Engineering Research and Applications, 5(2): 97-103. https://uwe-repository.worktribe.com/output/6726638.
[32] Tharmaratnam, K., Tan, B.S. (1990). Attenuation of ultrasonic pulse in cement mortar. Cement and Concrete Research, 20(3): 335-345. https://doi.org/10.1016/0008-8846(90)90022-P
[33] Altlomate, A., Alatshan, F., Elkher, M., et al. (2018). Evaluate the current expressions of compression strength and UPV relationship. International Journal of Integrated Engineering, 10(8): 33-37. https://publisher.uthm.edu.my/ojs/index.php/ijie/article/view/2461.