Mohammed-Amin Boumehraz[1], Farida Boucetta[2], Achref Hamaidia[3], Mekki Mellas[4],Kamel Goudjil[5]

[1]Department of Civil Engineering, University of Jijel, Jijel, Algeria, [1,4]Laboratory of Research in Civil Engineering (LRGC), University of Biskra, Biskra, Algeria, [2]Laboratory of Physics of Thin Films and Applications, University of Biskra, Biskra, Algeria, [3]Department of Civil Engineering, Mohamed-Cherif Messaadia, University of Souk Ahras, Souk Ahras, Algeria, [5]Laboratory INFRARES, Department of Civil Engineering, Mohamed-Cherif Messaadia, University of Souk Ahras, Algeria.

Scientificpaper
ISSN 0351-9465, E-ISSN 2466-2585
https://doi.org/10.62638/ZasMat1415

Zastita Materijala 67 (3)
551 - 560 (2026)

Study of the mechanical behavior of fiber-reinforced concrete through non-destructive testing

ABSTRACT

Several non-destructive mechanical tests can be used to assess the strength of concrete or mortar without crushing the specimens. In this study, prismatic specimens of glass fiber-reinforced concrete (GFRC) with different percentages (0%, 1%, 3%, and 5%) of ARHP-type glass fibers (high-performance alkali-resistant fibers) were used. Additionally, these GFRC specimens were exposed to different environments. A control series was kept in potable water, while the other series were maintained in seawater or a sulfate-rich environment. These specimens underwent mechanical and chemical tests. The results showed that adding fibers in proportions ranging from 1% to 5% slightly improved the density and strength of the concrete. However, immersing the GFRC specimens in a humid environment negatively affected the mechanical strength of the concrete, compromising its durability. Furthermore, it was observed that the carbonation depth was zero for all control specimens and those stored in seawater. Finally, the addition of 3% silica fume to the GFRC led to a slight improvement in strength but did not provide sufficient protection against the chemical degradation of fibers caused by alkaline or humid environments.

Keywords: *Non-destructive, ARHP fibers, seawater, Ultrasonic pulse velocity, XRF analysis.*

1. INTRODUCTION

Since the 20th century, reinforced concrete has established itself as theprimary construction material worldwide due to its strong performance in terms of resistance and durability. Recently, special types of concrete have been developed to address various challenges in the industry, including dense reinforcement and complex-shaped structures. However, reinforced concrete structures can be damaged by deterioration factors related to climate, both due to extreme environmental events and daily exposure to outdoor weather conditions [1-3]. Non-destructive testing techniques (NDT) are commonly used to analyze the causes of damage and implement repair actions aimed at extending the lifespan of reinforced concrete buildings. These techniques are widely applied in the field to assess the characteristics of concrete in existing and historical buildings. They not only help characterize material properties in concrete structures but also provide a comprehensive view of concrete quality. Regarding material properties, frequency-domain data is obtained through signal processing and sound vibration analysis, while visualization relies on a laser-based approach [1-4]. NDT methods used in civil engineering are generally designed to assess the condition of concrete. A comprehensive evaluation combining the simultaneous examination of both the concrete and the reinforcement can be carried out using the following techniques: ultrasonic testing, acoustic emission testing, low-frequency mechanical wave testing, and infrared thermography. These four groups of methods allow for the analysis of reinforcement in reinforced concrete structures. However, their effectiveness is inherently limited by several factors, such as the thickness of the concrete cover, the mix composition, the nature and quantity of aggregates, air voids in the concrete, contaminants, cracks, and other irregularities. Additionally, the Ultrasonic Pulse Velocity (UPV) test procedure is based on the concept of wave propagation speed through a solid object, which depends on the elastic properties of a tangible medium. When used correctly, this tool

*Corresponding author: Mohammed-Amin Boumehraz
E-mail: boumehraz.m.a@univ-jijel.dz

Paper received: 28.03.2025.
Paper corrected: 22. 02. 2026.
Paper accepted: 04.03.2026.

provides valuable information about the condition of the surface or the interior of the concrete [2-5].

Fiber-reinforced concrete is a composite material consisting of short, discontinuous fibers randomly distributed throughout the concrete mass. Cement-based composites typically incorporate fibers made of steel, glass, polymers, or natural resources [6]. Glass fibers are known for their high tensile strength, low density, and resistance to environmental degradation. During the setting phase, concrete mixtures tend to undergo plastic shrinkage, which can lead to cracking. The addition of small amounts of fibers effectively prevents cracks caused by early-age plastic shrinkage [7-8]. Kumar et al. (2022) found that the compressive strength of concrete decreases when the glass fiber content is less than 0.5% of the cement content. In contrast, samples containing 1.0% and 1.5% glass fibers showed a notable increase in compressive strength, reaching approximately 1.6% and 7.37% after 7 days of normal curing. Furthermore, after 28 days of normal curing, this increase was recorded at 13.88% and 18.99% [9].

Portland cement mortars reinforced with fibers contain alkali-resistant (AR) and non-dispersible glass fibers, ensuring good stability within the cement matrix. The use of AR glass fibers rich in zirconium oxide is recommended, as they withstand the alkaline pH generated during cement hydration [10]. The AR glass fibers help improve the chemical resistance of glass fibers reinforced concrete (GFRC). This property is essential in environments where concrete is exposed to aggressive chemicals [11]. Numerous studies have shown that glass fibers within cementitious composites undergo long-term deterioration. AR glass fibers are specifically designed to withstand degradation caused by cementitious matrices. This enhanced resistance is achieved by incorporating zirconium oxide (ZrO_2) into the fiber's chemical composition, which effectively inhibits attack from these matrices [12-14].

The use of mineral additives such as pozzolans, fly ash, and silica fume as a partial replacement for Portland cement improves the mechanical performance of GFRC. The cement matrix is modified by reducing calcium hydroxide, as the reaction of pozzolans with portlandite produced during cement hydration generates hydrated phases that do not compromise fiber integrity. This results in enhanced mechanical properties and increased composite durability over time [10]. Shameem et al. (2024) found that the compressive strength of GFRC with silica fume at 28 days is highest in the mix containing 1% glass fibers and 25% silica fume, leading to a 13% increase in strength compared to other types of concrete. The highest splitting tensile strength at 28 days was observed in the mix containing 1% glass fibers and 15% silica fume. A 40% increase in splitting tensile strength was recorded compared to conventional concrete [15]. The rate of aging depends on the specific type of glass fiber used. Notably, the new generation of alkali-resistant (AR) glass fibers outperforms traditional (E) glass fibers in terms of aging resistance. To further enhance the composite's aging performance under various environmental or weather conditions, the development of specialized glass fibers with even greater alkali resistance is an ongoing pursuit [16].AR fibers with lengths of 8 to 30mm and percentages of 0.3, 0.6, 0.9, and 1.2% by weight of cement were incorporated as additives in high-strength concrete. It was reported that the addition of fibers from 0 to 1.2% improved split tensile strength from 3.06 to 4.92MPa, while flexural strength increased from 4.84 to 7.27MPa [17]. When comparing the performance of fibers in terms of enhancing mechanical properties based on material, steel fiber has proven more effective in enhancing the mechanical properties of ordinary concrete than glass fiber and polypropylene fiber. Similarly, 0.25 to 1% glass fiber would increase compressive and flexural strength by 3 to 7% and 25 to 28%, respectively [18].Portlandite fills spaces between fiber filaments, creating a rigid bond that reduces fiber flexibility. Pan et al. (2017) found that incorporating 10-20% slag into mortar produced higher compressive strength compared to 30-50% slag at 28 days [19]. Sadati et al (2017), reported that adding 0-12.5% silica fume to concrete with a water-cement ratio of 0.4-0.5 altered its microstructure and decreased chloride ion diffusion [20].Non-destructive tests, particularly ultrasonic testing, enable a more accurate assessment of the degradation and microcracking of beams and complement destructive tests to better understand structural behavior. Since the compressive strength of specimens is sometimes not representative of the in-place concrete, the development of in-situ testing aims to provide a more reliable evaluation of the actual properties of structures [21, 22]. This research was conducted in the laboratory with the objective of testing the evolution of the characteristics of high-performanceAR glass fiber-reinforced concrete (GFRC) immersed in different environments, by using of non-destructive testing (NDT).

2. MATERIALS USED

2.1. Cement

The cement used in this study is Sulfate-resistant cement (SRC), which is manufactured at the LAFARGE cement Factory - Algeria.

2.2. Fibers

In this study, different percentages (0%, 1%, 3%, and 5%) of AR-type chopped glass fibers are used in the mixes. These fibers are of the high-performance alkali-resistant Cem-Fil type (ARHP 67/36) and have lengths of 36mm. They are characterized by their zirconium (ZrO_2) enrichment of 16.80%, which provides better durability against the alkaline attack of cement [23].

2.3. Aggregates

The aggregates used are as follows: siliceous sand with a grain size of less than 4mm, and crushed gravel of granular classes (3/8) and (8/16).Theses granulometric analysis curves of the aggregate are presented in Figure 1.

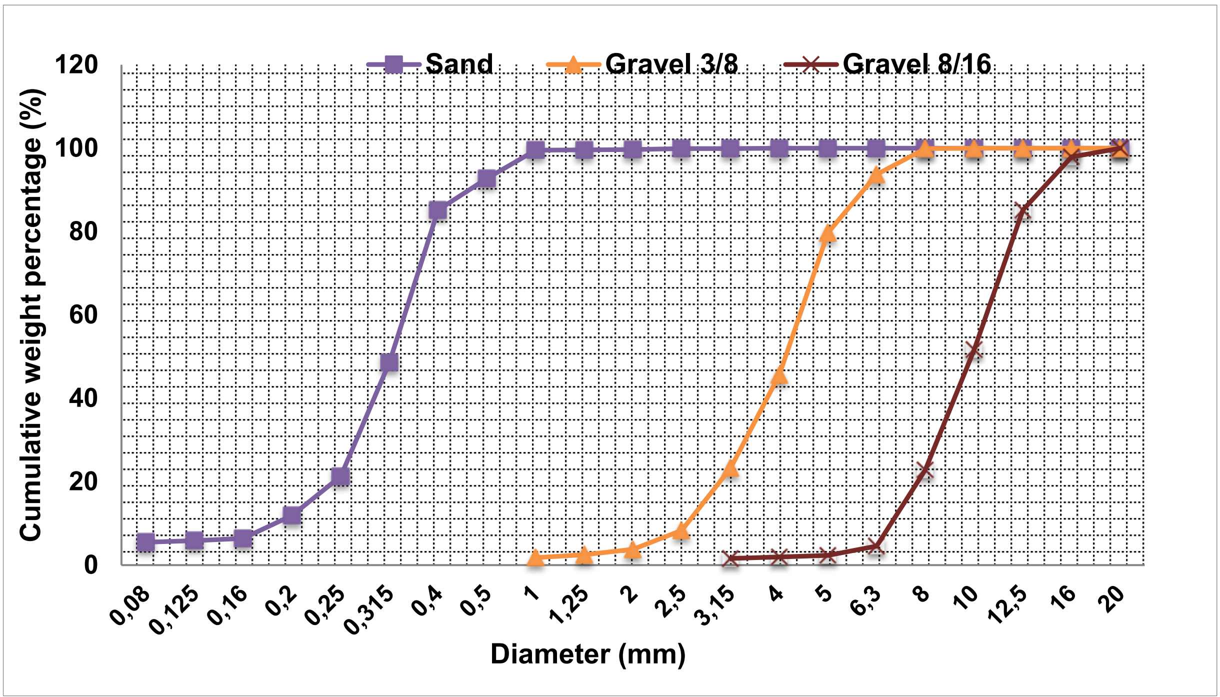

Figure 1. Granulometric analysis of aggregate

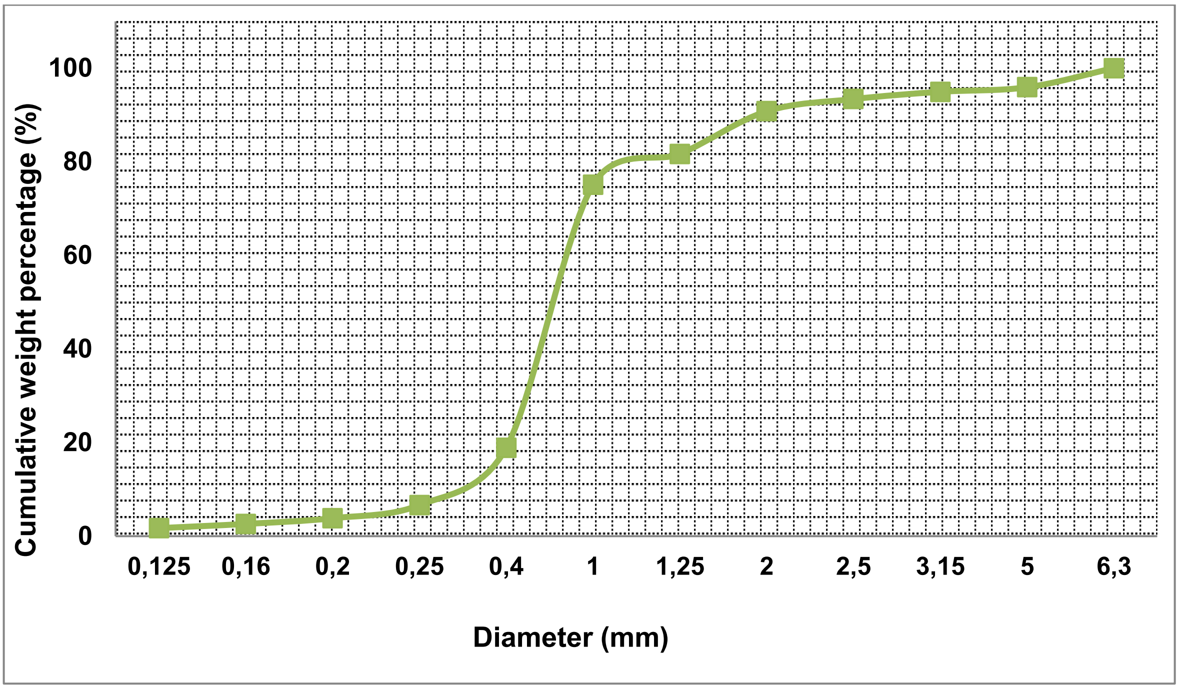

Figure 2. Granulometric analysis of blast furnace slag

2.4. Mineral Additions

The silica fume used is an ultra-fine grey silica with a specific Blaine surface area of 23m²/g [24]. The blast furnace slag used has a low percentage of fine elements less than 0.125 mm according to its granulometric analysis curve (see Figure 2).

3. PREPARATION AND PRESERVATION OF SPECIMENS

For this study, concrete formulations based on the DreuxGorisse and LCPC Baron-Lesage methods were used to determine the composition of concrete with and without fibers. After evaluating workability, the water-to-(cement + Blast furnace slag + Silica fume), ratio was fixed at 0.42 and the sand-to-gravel ratio at 0.6 for glass fiber percentages of 0%, 1%, 3%, and 5%. The table 1 presents the concrete formulation results using the DreuxGorisse method. Prismatic molds with dimensions of (70X70X280)mm³, conforming to European standard NF P 18-427, were used to fabricate GFRC samples. Following concrete pouring, the first set of control specimens (R) was submerged in a tank containing potable water within the laboratory.

A second set of specimens was immersed in a tank filled with seawater (SW) sourced from Jijel-Algeria. The seawater used for curing mainly contains chloride, sodium, magnesium, calcium, and potassium ions. It is considered aggressive due to its sulfate (SO_4^{2-}) concentration of1449 mg/l and magnesium (Mg^{2+}) concentration of 1366 mg/l, which fall within the range of 600 to 1500 mg/l. This water also exhibits high salinity, indicating a high content of dissolved mineral salts. Moreover, its high chloride concentration further increases its aggressiveness and leads to a significant risk of reinforcement corrosion in concrete structures [25].

Both sets were maintained in their respective environments until testing at 30, 90, and 180 days.

Table 1.Masses of concrete constituents

Cement (Kg)	Blast furnace slag (Kg)	Silica fume (Kg)	Sand (Kg)	Gravel 3/8 (Kg)	Gravel 8/15 (Kg)	Superplatisar (%)
308	80	12	536,07	270,72	1134,70	1,50

4. RESULTS AND DISCUSSIONS

4.1. Ultrasonic pulse velocity (UPV)

This test aims to determine the speed of propagation of sonic waves in concrete specimens according to the standard NFP 18-418 using an ultrasonic device, this device is made up of an electrical pulse generator, several transducers (a transmitter, one or more receivers), a timing device for measuring the time interval between the transmitter and the receiver by using oiled material (see Figure 3).

Figure 3. Ultrasonic Pulse Velocity (UPV) testing on GFRC specimens in the laboratory

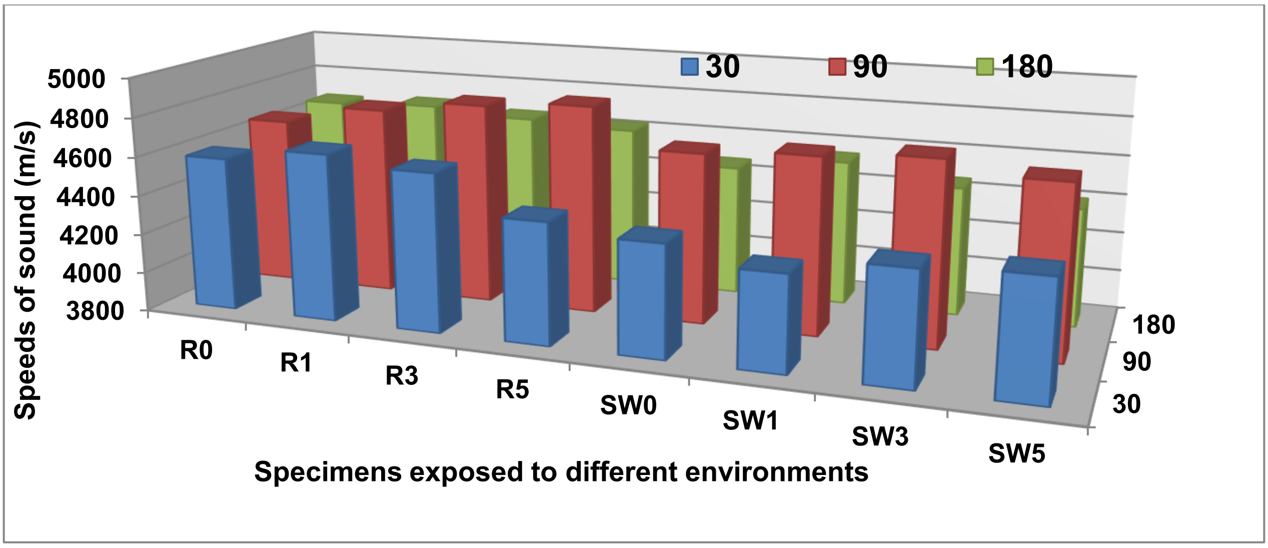

Figure 4. Propagation speed of sound in the control samples and those preserved in seawater

The ultrasound is calibrated using a cylindrical plastic bar, it is characterized by flat faces perpendicular to the axis of the cylinder, this bar has a diameter of (20 ± 0.1)mm and a length that varies between 80 and 120mm. The speed of sound is higher as the concrete is denser, therefore more resistant; this test was carried in laboratory, by taking four (04) test pieces in each test series. Figure 4 presents the measured sound propagation speeds of specimens exposed to different environments.

According to Figure 4, the following observations were made:

- The propagation speed of sound in the samples exposed to different environments gradually increased up to 90 days, then decreased until 180 days.
- The sound velocity is higher for specimens at 90 days compared to those at 30 days and 180 days of curing. This indicates that a higher sound velocity is associated with denser or stronger concrete.
- The control samples exhibited higher strength than those immersed in seawater. For example, at 180 days, the SW0, SW1, SW3, and SW5 samples recorded velocity reductions of 4.2%, 3%, 4.2%, and 4.9%, respectively, compared to their corresponding control counterparts (R0, R1, R3, and R5).
- The reduction in sound velocity can be explained by the decrease in the density of GFRC preserved in seawater. Likewise, it can be attributed to the dissolution of the silica network in the glass fibers or to an alkaline attack induced by sodium ions from seawater [26, 27].

4.2. Results of compressive strengths

Figure 5 shows the curve of compressive strengths of specimens stored in different environments. This curve was obtained using the correlation curve established between the compressive strengths of concrete and the corresponding ultrasonic velocities «V» [28].

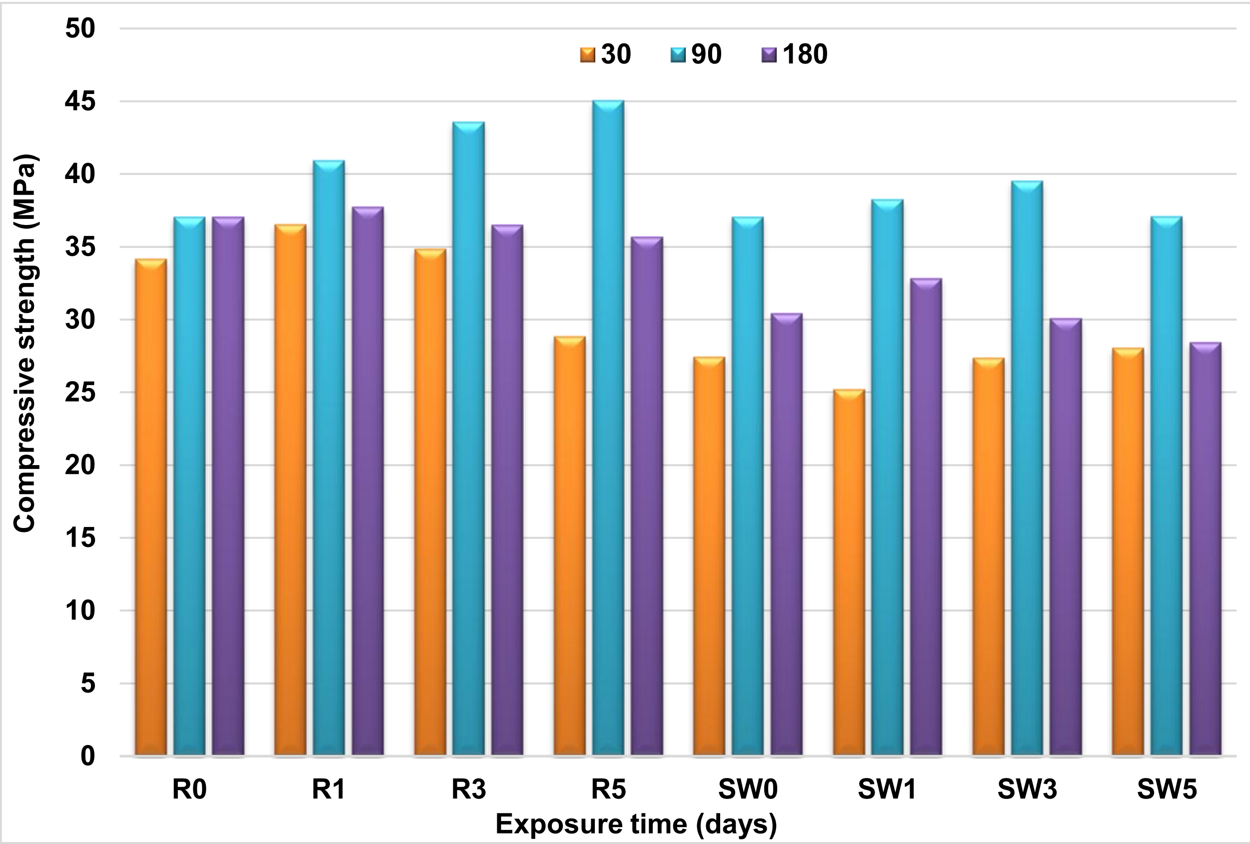

Figure 5. Compressive strength of concrete specimens preserved in different environment

The figure 5 shows that:

- The compressive strengths of the control samples are higher than those of the specimens stored in seawater.
- The compressive strengths of the specimens from R0 to SW5 increase up to 90 days of age, where they reach the values of 37.05 MPa, 40.92 MPa, 43.55 MPa, 45.05 MPa, 37.05

MPa, 38.24 MPa, 39.51 MPa and 37.09 MPa, respectively. These results can be attributed to cement hydration and the formation of C-S-H due to the effect of wet curing of the GFRC [29].

- After 90 days of age, the compressive strengths are reduced up to 180 days of storage, these results can be justified by the negative effect of wet curing of the GFRC. The addition of 3% silica fume results in a slight improvement in strength, but does not provide sufficient protection against chemical attacks in alkaline or humid environments. According to Arabi et al., [13, 14] this dosage only allows for modest reinforcement and does not effectively protect the fiber surfaces. Moreover, silica fume mitigates fiber degradation through its pozzolanic effect, which converts portlandite into C-S-H and reduces the porosity of the BRFV.
- The compressive strengths of specimens preserved in seawater are low compared to control specimens at the same storage ages. Therefore, seawater is a very alkaline environment, which could explain the loss of strength due to alkaline attack on AR fibers, resulting in the accumulation of calcium hydroxide, leading to excessive bonding and subsequent weakening of the GFRC [30]. According to Abdullah et al. [31], the compressive strength increases with increasing AR fiber content.
- The R5 and SW5 specimens exhibit the lowest compressive strength at almost all curing ages compared with the other series. This reduction is attributed to the high content of incorporated ARHP fibers and their length of 35 mm. A dosage of 5% decreases the workability of the mixture, which negatively affects the compressive mechanical performance of the concrete [9, 15].

4.3. Carbonation depth measurement test

This test is carried out on the surfaces of the specimens under the same test conditions using a phenolphthalein alcohol solution. This test allows for a reliable and quick measurement of the carbonation depth of the concrete specimens [32]. The carbonation depth value is the average of three (03) concrete specimens in each test period.It was found that the carbonation depth of the control specimens and those kept in seawater is zero from 30 to 180 days of conservation. Therefore, immersing GFRC in potable water and/or seawater reduces the diffusion rate of carbon dioxide into their pores, as water prevents the penetration of carbon dioxide gas.

4.4. Chemical Analysis by X-Ray Fluorescence Spectrometry (XRF)

The table 2 summarizes the results of the chemical analyses by XRF spectrometry of the surfaces of the GFRC specimens preserved in different environments.

According to table 2, we observe that:

- Zirconium (ZrO_2) is only found in specimens reinforced with glass fibers because it is a component of ARHP glass fibers.
- The levels of sulfates (SO_3), chlorides (Cl), sodium oxide (Na_2O), potassium oxide (K_2O) and magnesium oxide (MgO) on the surfaces of samples preserved in seawater are high; almost double those of the control specimens. These results confirm the high content of these elements in seawater.
- Calcium oxide (CaO) and Silicon dioxide (SiO_2) are the most intense elements on the surfaces of the control specimens and those preserved in seawater. It is also noted that the percentages are almost the same for all conservation environments.
- The other elements show similar percentages for each type of sample preservation.

Table 2. XRF analysis results of concrete preserved in different environments

Components	Potable water				Sea water			
	R_0(%)	R_1(%)	R_3 (%)	R_5(%)	SW_0(%)	SW_1(%)	SW_3(%)	SW_5(%)
MgO	1,18	1,43	1,34	1,26	2,07	3,03	3,19	4,91
Al_2O_3	2,56	2,41	2,27	2,43	2,44	2,72	2,50	2,85
SiO_2	17,90	18,40	17,30	18,50	18,20	20,80	20,60	19,10
P_2O_5	0,071	0,10	0,08	0,09	0,07	0,10	0,08	0,08
SO_3	1,17	0,99	1,15	1,11	1,37	1,80	2,32	2,07
K_2O	0,263	0,39	0,26	0,33	0,43	0,33	0,33	0,30
CaO	73,00	72,20	73,10	71,30	70,30	65,20	63,90	62,70
Fe_2O_3	3,73	3,61	3,63	3,56	3,70	3,58	3,63	3,81
SrO	0,10	0,08	0,08	0,09	0,10	0,09	0,09	0,08
Na_2O	-	0,25	0,30	0,55	0,45	0,53	0,65	1,00
ZrO_2	-	0,10	0,32	0,70	-	0,18	0,34	0,85
Cl	-	-	0,12	0,09	0,87	1,70	2,29	2,22

4.5. Visual Observations of GFRC Specimens

The visual observations of the faces of GFRC specimens preserved in different environments over one year are illustrated in Figure 6A protective white layer (salt layer from seawater) formed on the faces of the specimens preserved in seawater (6.A). In contrast, no layer was observed on the faces of the control samples (6B). Finally, it was noted that no visible damage could be seen with the naked eye on the glass fibers preserved in different environments (6C).

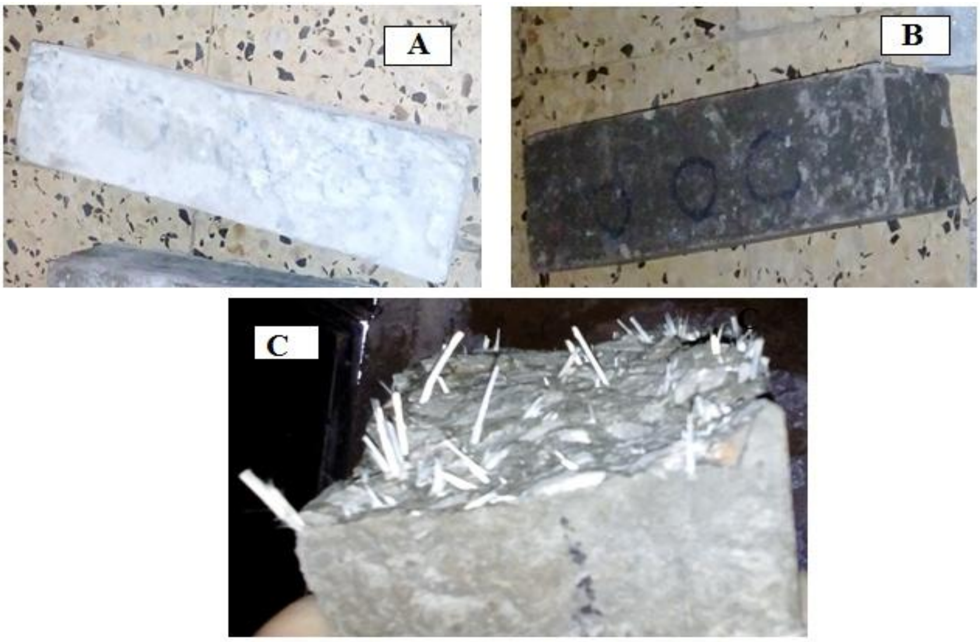

Figure 6. Fiber-reinforced concrete specimens after 365 days of preservation in different environments

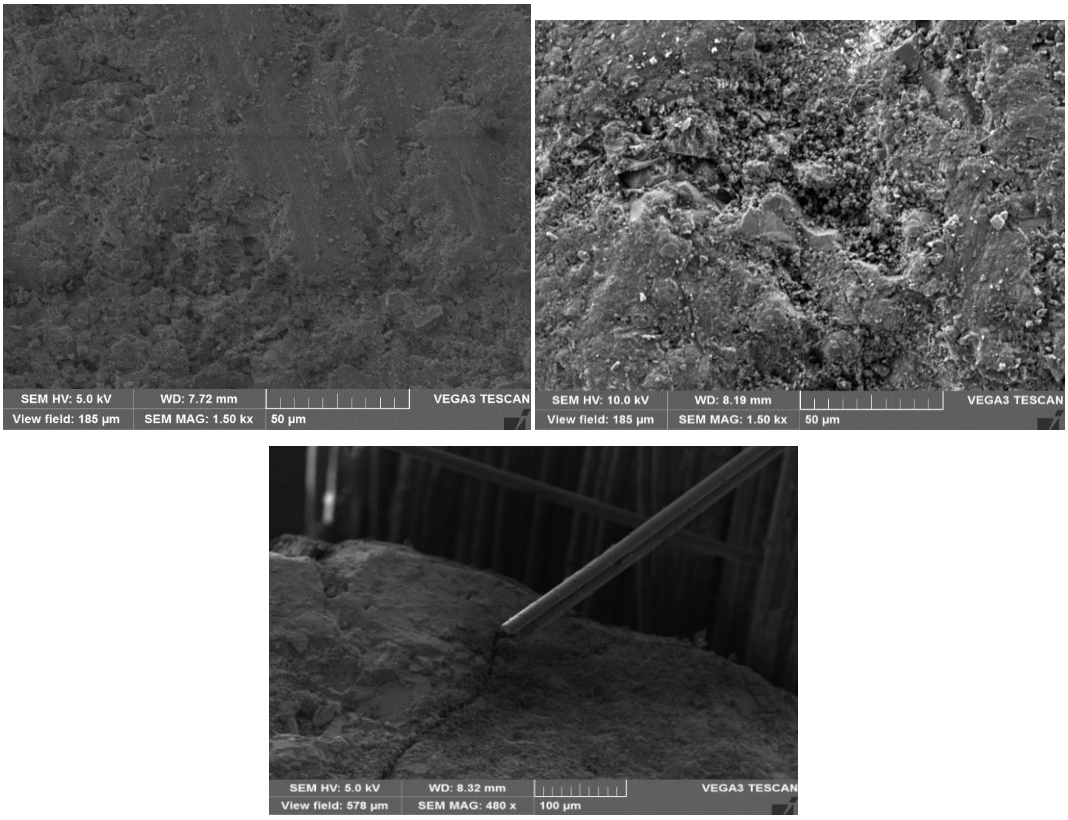

Figure 7.SEM observation of concrete and fiber preserved in seawater

4.6. SEM test results

The observation of GFRC samples stored in seawater is presented in the Figures 7. These images reveal surface degradations on the fiber filaments,likely caused during the mixing and/or casting of the concrete. Additionally, after storage in seawater, the hydrated cementitious matrix appears to have a loose microstructure due to the formation of microcracks in the cement paste surrounding the fiber filaments. Furthermore, precipitated crystalline products are visible on the surface of the concrete sample, potentially consistingof portlandite, gypsum, or ettringite.

These observations confirm a reduction in mechanical strength after 180 days of storage in a humid environment.

5. CONCLUSION

This study demonstrates that concrete reinforced with:

- The reduction in the speed of sound can be explained by the decrease in the density of GFRC stored in seawater compared to the control samples or those stored in drinking water.
- Alkali-Resistant High Performance (ARHP) fibers exhibit superior mechanical properties compared to unreinforced concrete. Optimal compressive strength was achieved with fiber volume fractions ranging from 1% to 5%.
- The addition of 3% silica fume in GFRC results in a slight improvement in strength but does not offer adequate protection against chemical attacks on the fibers caused by alkaline or humid environments.
- After a 180 days immersion period, neither control nor seawater-exposed specimens exhibited carbonation. However, both environments effectively impeded the diffusion of carbon dioxide into the GFRC pores.
- Finally, it can be concluded that the use of GFRC in underground works or humid environments remains limited due to its relatively low long-term durability and the detrimental effect of moisture on the strength of the AR glass fibers incorporated in the GFRC.

6. REFERENCES

[1] G. Boccacci, F. Frasca, C. Bertolin,A.M. Siani(2024).Diagnosis of Historic Reinforced Concrete Buildings: A Literature Review of Non-Destructive Testing (NDT) Techniques. Procedia Structural Integrity, 55, 160-167. https://doi.org/10.1016/j.prostr.2024.02.021.

[2] P.K. Frankowski, P. Majzner, M. Mąka, T. Stawicki, T. Chady (2024). Magnetic Non-Destructive Evaluation of Reinforced Concrete Structures—Methodology, System, and Identification Results. Applied Sciences, 14(24), 11695. https://doi.org/10.3390/app1424 11695.

[3] A. El-Nemr,I.G. Shaaban (2024). Assessment of special rubberized concrete types utilizing portable non-destructive tests. NDT, 2(3), 160-189. https://doi.org/10.3390/ndt2030010.

[4] S. Sayyar-Roudsari, A. Shalbaftabar, F.Damirchilo, R.Taslimian, T. Abu-Lebdeh, S. Hamoush, S. Yi (2024). Defect Classification of Reinforced Concrete Structures with Nondestructive Tests Using Statistical and Machine Learning Methods. American Journal of Engineering and Applied Sciences, 17(3), 102-115. https://doi.org/ 10.3844/ajeassp.2024.102.115.

[5] Z. Citra, P.D. Wibowo, Y. Malinda, A. Wibisono, R. Apdeni, H. Herol (2024). Testing of Concrete Structures with Non-Destructive Test Method (NDT) Using Ultrasonic Pulse Velocity (UPV) at the Building on the Ancol Beach. CIVED, 11(1), 217-225.https://doi.org/10.24036/cived.v11i1.530.

[6] R. Karthick, N. Gokulnath, G. Silambarasan (2024). Experimental Analysis on Partial Replacement of Cement by Glass Powder and Using of Steel Fiber. International Journal for Research in Applied Science and Engineering Technology (IJRASET), 12(3), 289-295. https://doi.org/10.22214/ ijraset.2024.58809.

[7] M. Tiwari, V. Hoonka, A. Kumar Khare, P. Tiwari, P. Jain (2019). Effect of Fiber Length and Orientation on the Mechanical Properties of Glass Reinforced Fibre Concrete. International Journal Of Multidisciplinary Research In Science, Engineering and Technology (IJMRSET), 2(9), 1846-1849. doi: 10.15680/IJMRSET.2019.0209010.

[8] N. Pannirselvam, S. Manivel (2021). Influence of Addition of Glass Fiber on Concrete. Innovative Solutions and Challenges in Civil Engineering (ISCCE 2020). IOP Conf. Series: Materials Science and Engineering (2021). doi: 10.1088/1757-899X/1026/1/012008.

[9] K. Kumar, S.A.Kumar (2022). Effect of Glass Fiber on Strength and Durability of Concrete. International Research Journal of Engineering and Technology (IRJET), 9(9), 1340-1347. https:// www.irjet.net/volume9-issue09-sep-2022.

[10] L.F. Lalinde, A. Mellado, M. V. Borrachero, J. Monzó, J. Payá (2022). Durability of Glass Fiber Reinforced Cement (GRC) Containing a High Proportion of Pozzolans. Applied Sciences, 12 (7), 3696.https://doi.org/ 10.3390/app12073696.

[11] M. Tiwari, V.Hoonka, A.K. Khare, P. Tiwari, P. Gupta (2018). Enhanced Durability of Glass Reinforced Fibre Concrete in Harsh Environmental Conditions. International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET), 1(2), 386-389. doi: 10.15680/IJMRSET. 2018.0102032.

[12] N.Arabi, B.Redjel, R.Jauberthie (2005).Influence des milieux de conservation sur la tenue des fibres de verre alcali-résistant dans une matrice cimentaire (CEM II/B 32,5R), Annales du bâtiment et des travaux publics, Matériaux, PP 19-24. https://fr.scribd.com/document/852811904/1037-5-19-24-ARABI-1.

[13] N. Arabi (2011). Influence of curing conditions on durability of alkali-resistant glass fibres in cement matrix. Bulletin of Materials Science, 34(4), 775. https: //doi.org/10.1007/s12034-011-0194-1.

[14] N. Arabi, L. Molez,D. Rangeard (2018). Durability of alkali-resistant glass fibers reinforced cement composite: Microstructural observations of degradation. Periodica Polytechnica Civil Engineering, 10631. https://doi.org/ 10.3311/PPci.10631.

[15] S. Shameem, V. Sharma (2024). Experimental investigation on the mechanical behavior of glass fibre-reinforced concrete with partial replacement of cement with silica fume. In E3S Web of Conferences (Vol. 596, P. 01028). EDP Sciences. https://doi. org/10.1051/e3sconf/202459601028.

[16] M. Iskender, B. Karasu(2018). Glass fibre reinforced concrete (GFRC). El-Cezerî Journal of Science and Engineering, 5(1), 136-162. https:// doi.org/10.31202/ecjse.371950.

[17] A. Paktiawal, M. Alam(2021). Experimental evaluation of sorptivity for high strength concrete reinforced with zirconia rich glass fiber and basalt fiber. Materials today: proceedings doi.org/ 10.1016/j. matpr.2021.06.008.

[18] B. Ali, L.A. Qureshi, S.U. Khan (2020). Flexural behavior of glass fiber-reinforced recycled aggregate concrete and its impact on the cost and carbon footprint of concrete pavement. Construction and Building Materials, 262 doi.org/10.1016/j.conbuildmat.2020.120820.

[19] C. Pan, M. Ling, D. Wei, J. Geng, J. Mao, W. Jin (2017). Effect of modified supplementary cementitious material on performance of mortar and concrete in marine environment. Journal of Shanghai Jiaotong University (Science), 22, 541-548.https://doi.org/10.1007/s12204-017-1873-x.

[20] S. Sadati, M.K. Moradllo, M. Shekarchi (2017). Long-term performance of silica fume concrete in soil exposure of marine environments. Journal of materials in civil engineering, 29(9), 04017126. https://doi.org/10.1061/(ASCE)MT.1943-5533. 00019

[21] M. Marković, M. Popović, D. Nikolić, D. Varevac, A. Savić (2025). Assessment of concrete and reinforced concrete beams incorporating CRT panel glass using non-destructive and destructive testing methods. Building, 15 (23), 4346. https://doi.org/10.3390/buildings15234346.

[22] A. Evangelista, A. Arumugam, M. Abate (2025). Evaluation of the parameters influencing the results of non-destructive testing methods for concrete strength. arXiv. doi: 10.20944/preprints 202508.1301.v1.

[23] M.A. Boumehraz, M. Mellas, K. Goudjil, F. Boucetta (2020). Study of the aging of a concrete reinforced by alkali resistant glass fiber in the wet environment. Annales de Chimie Science des Matériaux, 44(02), PP. 85-90.https://doi.org/10.18280 /acsm.440202.

[24] Fiche technique. Fumée de silice densifiée mécaniquement pour bétons hautes performances et haute durabilité, Usine de Sika, Alger.

[25] M.A. Boumehraz, M. Mellas, K. Goudjil, F. Boucetta (2019). Durability of GCB concrete exposed to sea water sulphates in the region of Jijel – Algeria. International journal of materials, Vol 06. https://www.naun.org/main/NAUN/materials/2019/a182018-050.pdf.

[26] P. Purnell, N.R. Short, C.L. Page(2001). A static fatigue model for the durability of glass-fibre reinforced cement.Journal of materials science, 36(22), 5385-5390. https:// doi.org/10.1023/A:1012496625210.

[27] J. Huang, R. Aboutaha(2010). Environmental reduction factors for GFRP bars used as concrete reinforcement: new scientific approach. Journal of composites for construction, 14(05), 479 - 486 doi: 10.1061/ASCECC.1943-5614.0000122.

[28] D. Boukhelkhal, S. Kenai(2015). Détermination non destructive de la résistance du Béton sur site (Scléromètre and Ultrason). Rencontres Universitaires de Génie Civil, May 2015, Bayonne, France.https://hal.science/hal-01167739.

[29] N.I. Makridin, I.N. Maksimova, D.V. Emelyanov, I.N. Burnaykin(2021). Study of the Hydration Kinetics of Cement Paste by Measuring Electrical Conductivity. In IOP Conference Series: Materials Science and Engineering, 1079(5), 052091). IOP Publishing. doi: 10.1088/1757-899X/1079/5/052091.

[30] X. Qian, B. Shen, B. Mu, Z. Li(2003). Enhancement of aging resistance of glass fiber reinforced cement. Materials and structures, 36 (05), 323 - 329, doi:10.1007/BF02480872.

[31] M.M. Abdullah, E.K. Jallo(2012). Mechanical properties of glass fiber reinforced concrete. Al-Rafidain engineering, 20(05).233-240, https://doi.org/10.33899/RENGJ.2012.61048.

[32] J. Baron and J.P. Ollivier(1992). La durabilité des bétons. Edition de l'école des ponts et chaussées, 49, Rue de l'université, 75007 Paris.

IZVOD

PROUČAVANJE MEHANIČKOG PONAŠANJA VLAKNIMA ARMIRANOG BETONA METODOM NEDESTRUKTIVNIH ISPITIVANJA

Nekoliko nedestruktivnih mehaničkihi spitivanja može se koristiti za procenu čvrstoće betona ili maltera bez drobljenja uzoraka. U ovoj studiji korišćeni su prizmatični uzorci betona armiranog staklenim vlaknima (GFRC) sa različitim procentima (0%, 1%, 3% i 5%) staklenih vlakana tipa ARHP (visokoperformansna vlakna otporna na alkalije). Pored toga, ovi GFRC uzorci bili su izloženi različitim sredinama. Kontrolna serija je čuvana u vodi za piće, dok su druge serije čuvane u morskoj vodi ili sredini bogatoj sulfatima. Ovi uzorci su podvrgnuti mehaničkim i hemijskim ispitivanjima. Rezultati su pokazali da dodavanje vlakana u proporcijama od 1% do 5% blago poboljšava gustinu i čvrstoću betona. Međutim, potapanje GFRC uzoraka u vlažnu sredinu negativno je uticalo na mehaničku čvrstoću betona, ugrožavajući njegovu trajnost. Štaviše, primećeno je da je dubina karbonizacije bila nula za sve kontrolne uzorke i one skladištene u morskoj vodi. Konačno, dodavanje 3% silicijumske prašine u GFRC dovelo je do blagog poboljšanja čvrstoće, ali nije pružilo dovoljnu zaštitu od hemijske degradacije vlakana izazvane alkalnim ili vlažnim sredinama.

Ključne reči*: Nedestruktivno, ARHP vlakna, morska voda, ultrazvučni impuls*

Naučni rad
Rad primljen: 28.03.2025.
Rad korigovan: 22.02.2026
Rad prihvaćen: 04.03.2026.

Mohammed-Amin Boumehraz https://orcid.org/0009-0006-2965-4560