International Journal of Engineering Trends and Technology
ISSN: 2231-5381/ https://doi.org/10.14445/22315381/IJETT-V74I11P107

Volume 74 Issue 11, 109-117, November 2026
© 2026 Seventh Sense Research Group®

Original Article

Performance Evaluation of Concrete with Groundnut Shell Ash and Discarded Nylon Fiber

Ebin Tom[1], Thanka Jebarsan Victor[2]

[1,2]*Department of Civil Engineering, Nooral Islam Centre for Higher Education, Thakalay, Tamilnadu, India.*

[1]*Corresponding Author: ebintom888@gmail.com*

Received: 21 May 2026 Revised: 19 August 2026 Accepted: 29 August 2026 Published: 25 November 2026

Abstract - *There is a need for eco-friendly alternatives since making concrete uses many natural resources and pollutes the air. The objective of this research is to investigate the properties of cement concrete that incorporates Groundnut Shell Ash (GNSA) and Discarded Nylon Fiber (DNF) as partial replacements for cement in the mixture. The study prepared concrete in various weight proportions across five distinct mixes to evaluate their durability, strength, and sustainability according to established standards. The results indicated the creation and evaluation of each varying in the proportions of GNSA and DNF, and it was conducted between the modified combinations, including 5–10% GNSA and 5–10% DNF and a control mix composed of 100% cement of specimen C1. The results show that GNSA is in charge of encouraging pozzolanic activity, while DNF is in charge of making things more ductile and resistant to breaking. The optimum blend improves the performance and has environmental benefits, which helps to create construction practices that are better for the environment by reducing waste and utilizing sustainable materials.*

Keywords - *Mechanical properties, Discarded Nylon Fiber, Ground Nut Shell Ash, and Sustainable environment.*

1. Introduction

Concrete is the most popular construction material due to its persistence over time, ability to be employed in many techniques, and capacity to handle the existence of usage. But production of concrete with too much cement is immoral for the environment and forms more carbon dioxide [1], contributing to climate change and environmental degradation. Using additional materials, containing waste from industries and farms, to increase concrete's performance and make it less dependent on cement is more ecologically responsible [2], as it not only reduces the carbon footprint associated with cement production but also promotes recycling and sustainability in construction practices. Researchers are currently looking at the possible advantages of utilizing GNSA and DNF in concrete.

Here are some examples of unique alternative resources. When burned in a specific manner, groundnut shells produce a substance known as groundnut shell ash. The pozzolanic compounds, like silica, in the substance, using chemicals in concrete as a partial substitute for cement, make the concrete last longer [3, 4]. Because of this performance, items become less porous, stronger under pressure, and last longer. It also utilized DNF, which is made from synthetic materials that have been using concrete to achieve benefits of making stronger concrete, more flexible, durable, and less likely to break.

Concrete with fibers is better at withstanding impacts, shrinkage cracks, and stresses. Fibers also help concrete not crack as it shrinks. It is expected that the combined effects of GNSA and DNF on concrete would enhance the material's overall mechanical properties, and it is also expected that these effects will make concrete more environmentally friendly. This study is to examine the quantity of GNSA and DNF that impact the workability, strength, and durability of concrete. The purpose of this project is to make a concrete mix that is cheap and good for the environment. The ultimate result will also help to spread the word about construction and recycling methods that are good for the environment. Adding parts made from trash will make these changes happen. Concrete is the most popular construction material, and as cities grow and their infrastructure grows, the need for it is growing. On the other hand, making conventional concrete causes many environmental problems, such as using up natural resources and releasing too much carbon dioxide during the cement-making process [5-7].

Researchers have been looking at different materials that might work with aggregates and cement for the previous several years. This is what they want to do to make items more eco-friendly while keeping or improving their mechanical performance [8]. There has been a lot of interest in agricultural and industrial waste materials because they can improve the properties of concrete and lessen its impact on the

This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

environment [9]. Burning groundnut shells, which are easy to procure and are a kind of waste from farming, may make GNSA. Using it this way makes the product more like cement since it contains silica and other pozzolanic ingredients. It is a partial replacement for cement and has these qualities. It is a partial replacement of cement and has such properties. Concrete mixed with ash from agricultural waste has been shown to be stronger, more durable and easier to work with [10]. Researchers have investigated the possibility of DNF, from synthetic residues, to improve the flexibility and failure resistance of concrete composites. DNF is a man-made material product that has been discarded after use. Fibers are an effective means of reinforcing concrete, enhancing the material's cracking behavior, increasing its resistance to stress and reducing its shrinkage [11-15]. In Table 1 indicates the Comparison between present and previous study. Although GNSA has been studied as a partial replacement of cement and DNF as a reinforcement material, there have been few studies on the combined use of GNSA and DNF in concrete. But the combined impact of GNSA and DNF on workability, mechanical strength, and durability is not well known. Thus, the present work bridges this gap via a systematic study on various proportions of GNSA and DNF to achieve an efficient, sustainable concrete mix.

This research is unusual in the aspect that it mixes GNSA and DNF in concrete, in which GNSA substitutes a portion of the cement, and DNF functions as a fiber-reinforcing element. The effect of agricultural waste ash and synthetic fibers on the performance of concrete was studied as compared to the previous studies that considered agricultural waste ash or synthetic fibers separately. Study on different combination of GNSA-DNF and their effect on workability, mechanical strength and durability.

The objective of this research is to study the effect of GNSA and DNF blend on the mechanical properties of concrete from a mechanical viewpoint. The present work aims at the study of methods to increase the durability and strength of concrete in tension and compression. This is achieved by adding DNF and replacing some of the cement with GNSA.

Different combinations of mixes were scientifically studied on durability, strength and service life. The research results recommend improving the use of recycled materials in concrete to reduce the reliance on ordinary cement and reduce environmental pollution regarding sustainable building elements. All these changes are to do with the building trade.

Table 1. Comparison between present and previous study

No.	Authors	Study	Key Relevance to Present Work
1	Akhnoukh et al. (2021)	Supplementary Cementitious Materials Effect on Alkali-Silica Reaction of Concrete	Emphasizes the significance of the use of Supplementary Cementitious Materials (SCMs) to enhance the performance of concrete and to minimize undesirable reactions.
2	Eu et al. (2024)	Residual mechanical properties and alkali silica reaction of high-strength mortar with SCMs	Studied the effect of SCM addition on ASR resistance and residual mechanical properties to promote the use of alternative cementitious materials.
3	Brykov et al. (2014)	Ultrafine Silica Additions in Long-Term ASR Expansion Tests	Shows the effect of silica-based additives on long-term concrete expansion and durability.
4	Langaro et al. (2021)	Rice husk ash as a supplementary cementitious material for mitigation of ASR	It shows the potential of agricultural waste ash as a supplementary cementitious material and promotes sustainable utilization of agricultural wastes.
5	Guerini et al. (2018)	Effect of synthetic fibers on properties of concrete	It provides a framework for the use of synthetic fibers to modify and improve characteristics of concrete, making possible the incorporation of DNF in the current work.
6	Papadakis (2000)	Effect of Supplementary Cementitious Materials on Resistance to Chloride Ion Penetration	It emphasizes the importance of SCMs in improving concrete durability and resistance to chloride ingress.
7	Thomas (2011)	Supplementary cementing materials and ASR	Reviews the importance of SCMs in reducing ASR and gives significant information on their contribution to durable concrete.
8	Shehata and Thomas (2002)	Mitigation of ASR by use of hybrid SCM blends.	The investigation of the combination of GNSA-DNF concrete is relevant to the study. It hints at potential synergistic effects between the combination of several other ingredients.
9	Radlinski and Olek (2012)	Synergistic effect of supplementary cementitious materials in the mitigation of ASR	Suggests that combinations of supplements could provide a performance benefit over individual supplements.

2. Materials and Methods

2.1. Materials Used

This study aims to examine how the properties of concrete change when it includes different amounts of GNSA and DNF. The research was conducted within the framework of the ongoing study, which ensured a uniform water-to-binder ratio across all five concrete formulations. Each concrete mix was defined by specific amounts of GNSA and DNF.

The concrete mixture included water, coarse aggregates made from crushed rock, fine aggregates from river sand, GNSA, DNF, and Ordinary Portland Cement (OPC 53 Grade). Fine, wet sand is also part of the blend, as shown in Table 2. The C1 composition was free of both GNSA and DNF, and the modified compositions, labeled C2 to C5, had DNF added at either 5% or 10% to improve the properties. This involved replacing some of the cement with GNSA, using either a 5% or 10% substitution. The inclusion of these two components aimed to improve the product's durability. First, they were mixed dry in an effort to obtain a homogeneous distribution of nanoparticles in the cementitious matrix and the produced sediments. The mixture was mixed well after the addition of water. The novel material obtained was then shaped into standard specimens to evaluate its strength, fracture resistance, water retention capacity and corrosion resistance. This process was applied to maintain the desired properties of the material. The material was cured for 7, 14 and 28 days to test the strength. The components underwent a series of technical and durability tests to determine the optimal amount of GNSA and DNF for effective concrete works

Table 2. Proposed composition of materials and quantities

Compositions	Notations	Cement (Kg)	Amount of GNSA (Kg)	Amount of DNF (Kg)	Sand (Kg)	Coarse aggregate (Kg)	Water (L)
C-100/GNSA-0/DNF-0	C1	360	0	0	745	1150	180
C-85/GNSA-5/DNF-5	C2	306	21	15	745	1150	180
C-85/GNSA-5/DNF-10	C3	306	21	30	745	1150	180
C-85/GNSA-10/DNF-0	C4	306	42	0	745	1150	180
C-85/GNSA-0/DNF-5	C5	306	0	15	745	1150	180

2.2. Testing of Concrete Specimens

The mechanical properties of concrete were determined by standard methods. In particular, to investigate the effects of GNSA and DNF on specimens after curing.

2.2.1. Determination of Compressive Strength

Compressive strength of concrete cubes of size 150 mm × 150 mm × 150 mm was tested using the Universal Testing Machine as per IS 516: 1959. The test was done on the 7th, 14th and 28th day after the curing period of the tested specimen.

2.2.2. Split Tensile Strength Test

The split tensile strength test was performed on cylindrical samples to test the indirect tensile loads on the concrete specimen. The samples were 150 mm by 300 mm. The results of this test were used to determine the strength of the concrete. The test was performed on DNF specimen using the diametrical loading technique as per IS 5816:1999, which showed better tearing and breaking strength.

2.2.3. Water Absorption Test

The water absorption test was used to evaluate the characteristics of porosity and permeability, in addition to the strength of the concrete. The percentage of water absorption was calculated by weighing cylindrical specimens dried in an oven before and after water immersion for 24 hours. The pozzolanic activity of GNSA resulted in a reduction in water absorption, indicating lower porosity and higher durability.

2.2.4. Rapid Chloride Penetration Test (RCPT)

Furthermore, the corrosion resistance of concrete was evaluated by the chloride ion permeability measurement using the RCPT.

Concrete disks of 100 mm by 50 mm were subjected to an alkaline solution on one side and a chloride on the other for six hours at 60V. Lower total charge passing values indicated higher resistance to chloride penetration.

2.2.5. Electrochemical Corrosion Assessment

The electrochemical corrosion test on the reinforced concrete beams with dimensions of 100 mm × 100 mm × 500 mm was used to examine the corrosion characteristics of the reinforcement.

To accelerate the corrosion process, specimens were partially immersed in a 3.5 % NaCl solution, and a constant 12V was applied. To measure the potential of corrosion of the steel reinforcement, a saturated calomel electrode was used to determine the most effective concentrations of GNSA and DNF in corrosion prevention.

Table 3. Characteristics of the materials employed

Material	Compressive Strength (MPa)	Tensile Strength (MPa)	Elastic Modulus (GPa)
Cement (OPC 53 Grade)	53	3.5	30
GNSA	9.5	1.25	7.8
DNF	--	590	2.9
Fine Aggregate (Sand)	34.5	2.9	58
Coarse Aggregate	101	7.1	71

2.3. Composition of the Mix

The M25 mix of cement concrete in accordance with IS 10262 and IS 456, and set strength of 32 MPa. These experiments where using GNSA and DNF of the proposed materials and replaced some amount of cement. These three compounds' weight proportions are shown in Table 3, which can be seen here. The water-to-binder ratio has remained at 0.5 throughout this process. The blend-to-percentage ratio is 1:2.069:3.194 for the M25 CC mix.

3. Results and Discussions

3.1. Compressive Strength of Concrete

A compressive strength test was applied to concrete samples containing DNF and GNSA for determining load-bearing capacity. The strength improvements were assessed at the curing periods of 7, 14, and 28 days. Mix, known as C1, was used for comparing the results of tests.

It was found that the mechanical properties of concrete improved by using pozzolanic material (GNSA) and fiber reinforcement (DNF) as additives during the mixing process. The use of GNSA significantly improved compressive strength, as confirmed from Figure 1.

This improvement was ascribed to its pozzolanic properties, which gave rise to more C-S-H gel. Additionally, the DNF samples exhibited an enhanced compressive stress resistance, thereby improving the cracking resistance. In accordance with previous studies [16-18], for composition C2, the fiber-cement-based concrete reinforcement was predominant. Meanwhile, the increase of DNF contents in C3 decreased the compressive strength slightly, owing to more voids and reduced workability.

The composition of C4 based on 10% GNSA but containing no DNF also performed very well, because the absence of fibers provided a loss in toughness, but the pozzolanic reaction still enhanced strength [19, 20]. GNSA and DNF modifications exhibited similar positive effects as observed in the control C1 mix, with the least strength.

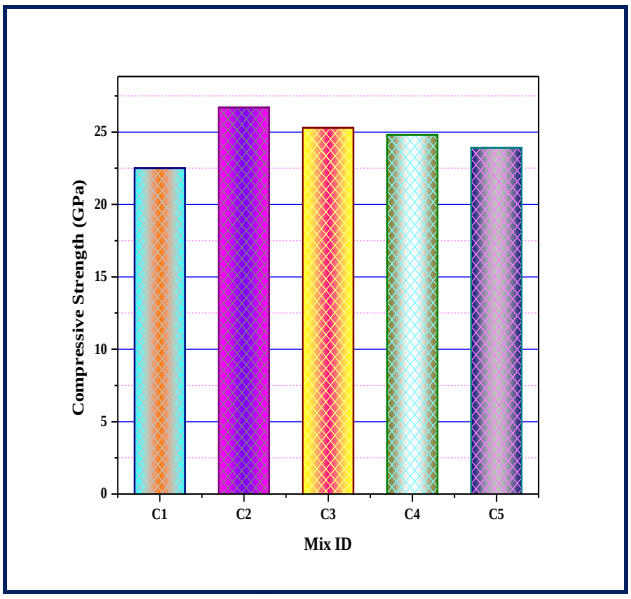

Fig. 1 Compressive strength of the concrete specimens at 7-day intervals

The results revealed that replacing 5% cement with C_2's GNSA also improved the compressive strength significantly. This led to increased hydration product formation in the pozzolanic reaction. Additionally, the incorporation of 5% DNF to formulate a bar enhanced ductility and fracture resistance to further improve its performance. At this moderate amount of DNF addition, the power of C3 declined sharply because its distribution was uneven in the composition matrix and balling phenomenon of fiber.

Concrete matured over time with 10% GNSA in composition C4 and showed significantly higher strength than concrete compositions that lacked the additive, so it could confirm that when GNSA is applied for concrete use, it can have positive results [21]. This mix was linked to less performance than mixes containing fibers.

The DNF with 5% only and without GNSA indicated that there was no other pozzolanic activity, still, it resulted in a greater strength over the control mixture. The upcoming results show that the synergism between GNSA and DNF can be considered a universal approach to improving concrete strength, which is a sustainable construction technique. Composition C2, which was the best mix, had the highest compressive strength. The beast is insanely light. GNSA and DNF structures help the Beast to offer you even better performance, as well as sustainability in construction.

3.2. Split Tensile Strength of Concrete

C2, made of 5% Glass Nano-Silica Aggregate (GNSA) and 5% Deformed Nylon Fibers (DNF), was performed best. This improvement was most likely due to the fiber reinforcement. It helped prevent the cement from breaking, as well as strengthened the ties between the materials. The 10% DNF of the C3 mix worked, making the performance sub-

optimal. This effect could be due to stress redistribution in the matrix when fiber clumping occurs. This results in less load distribution and a greater likelihood of failure under pressure.

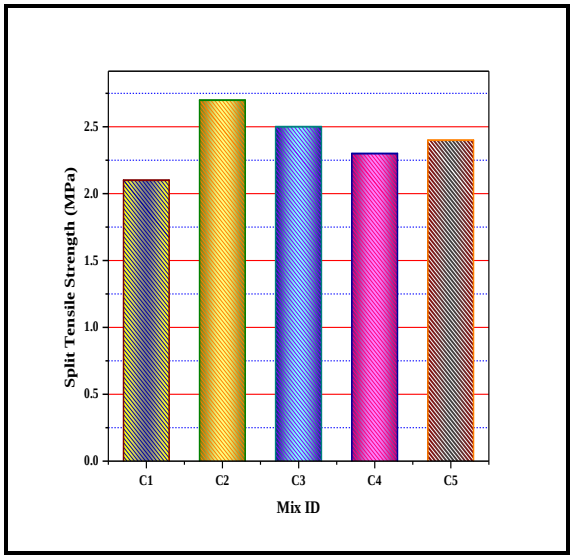

Fig. 2 The split tensile strength of the concrete specimens at 7 days

On the other hand, the tensile strength for the C4 mix, where 10% GNSA was included but no fiber reinforcing was added, did increase somewhat (see Figure 2) but still remained low overall. This was probably due to the pozzolanic effect of the GNSA [22]. All the same, without any fibers in the concrete, it couldn't deal with tensile tension. GNSA and DNF obviously performed well in improving tensile properties since control mix C1 had the lowest tensile strength. The observation from split tensile strength is that, integrated together, GNSA and DNF have improved the tensile characteristics of concrete. The composition that exhibited the highest tensile strength was C2, comprising 5% GNSA and 5% DNF. GNSA appears to have enhanced the strength and density of connections between concrete particles. Meanwhile, DNF proved it could prevent breaks from forming. However, Composition C3 had a higher fiber fraction and a slight reduction in tensile strength. The results suggested that the fibers were not sufficiently dispersed, and the agglomeration of fiber led to hindrance in stress transfer.

While the statistically significant increase in strength of composition C4 (which consisted of 10% GNSA and did not contain any DNF) is absolutely undeniable, it was unable to withstand tensile stress because there were no fibers present. C1 was the least strength (control mixture). This indicates that the addition of GNSA and DNF improves the compressive strength of concrete under stress. These results demonstrate that the addition of appropriate content of fibers as a reinforcing agent to pozzolanic material significantly improves both tensile strength and durability characteristics of concrete. This finding means it is a more durable and environmentally friendly building material.

3.3. The Water Absorption Test

The porosity and permeability of concrete incorporated with GNSA along DNF were checked by the immersion test. The amount of time that concrete is able to stay strong depends heavily on how much water it absorbs. This process leads to porosity of the concrete, which makes it weak and non-durable. Testing was performed utilizing cylindrical (100 mm by 200 mm) specimens that had been allowed to cure for a duration of 28 days. The samples were dried (W_1) at 105 degrees Celsius for 24 hours, immersed in water for another 24 hours, and weighed again (W_2). To calculate the amount of water absorbed, for used the following formula:

$$\text{Water Absorption (\%)} = \frac{W2-W1}{W1}\times 100$$

Figure 3 displays the relevant statistics, indicating that the combined action of GNSA and DNF dramatically affects water absorption. Since composition C1, the control mixture, contains 100% cementitious materials along with no additives designed to improve pore structure, this mixture exhibited the highest degree of water absorption.

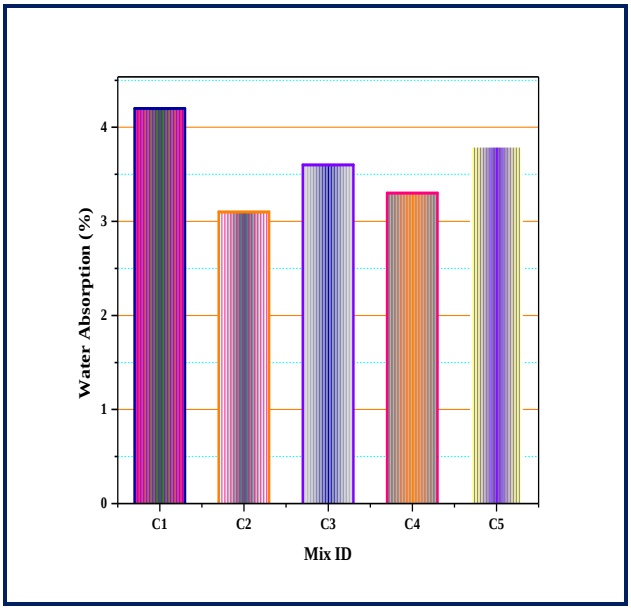

Fig. 3 Concrete specimens' water absorption test results at 7 days

The curing 10% GNSA concrete composition C4 demonstrated lower water absorption, indicating the pozzolanic properties of GNSA; this finding helps in microstructural densification and filling up voids [23, 24]. Composition C2 shows that the combination with 5% GNSA and 5% DNF can only bind a bit of water. This effect is likely due to the pozzolanic activity combined with fiber reinforcement that results in a less porous, stronger mix. Alternatively, excessive amounts of DNF used in C3 tend to improve water absorption. The issue could be due to insufficient spread of the fiber, leading to an increased void content.

The results indicate GNSA and DNF, when added to concrete, could make it better at soaking up water. Of all the materials, Composition C2 recorded the lowest absorption. That was comprised of 5% GNSA and 5% DNF. The balancing of the pozzolanic activity with the fiber reinforcement was clearly evident from this result.

This combination allowed the particles to pack more tightly and made the material less permeable. The protective effect of the mixture containing 10% GNSA (composition C4) against water penetration was significantly higher than that of other groups. This study confirms that, indeed, GNSA makes concrete particles less porous.

On the other hand, a small increase in absorption that occurred due to clustering of excessive fibers in composition C3 may be responsible for the generation of microvoids within the concrete matrix. Overall, the results support GNSA and DNF increasing concrete durability by reducing permeability, which in turn increases its lifetime. As reported in [25, 26], the highest absorption was by a control mixture of Composition C1. That means regular concrete without additional portions had greater pores. The results imply that concrete might work better with a balanced proportion of these compounds. This would allow it to linger longer in buildings and make it less likely to become wet.

3.4. Rapid Chloride Penetration Test (RCPT)

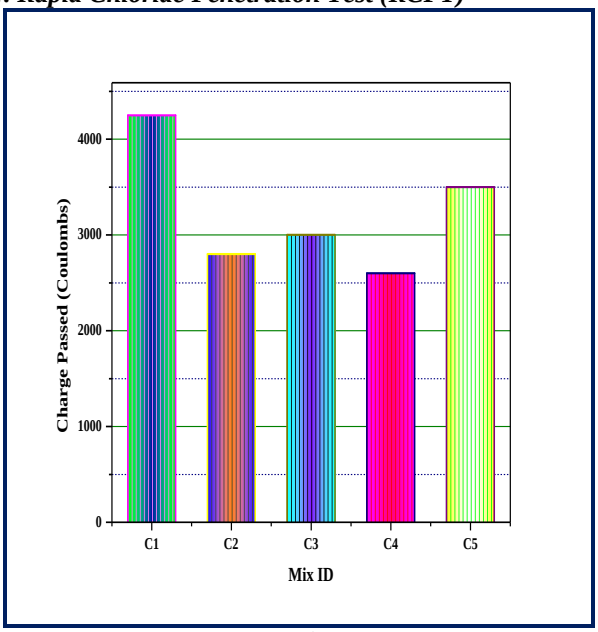

Fig. 4 The RCPT results of the concrete specimens

For used the RCPT to determine how efficiently chloride ions are able to penetrate into concrete. The RCPT is a very valuable tool to predict how long something will last, especially in challenging environments. Chlorides are negatively charged ions, which make corrosion of implanted reinforcement fast and shorten the life span of a building.

The test, which adhered to ASTM C1202 guidelines, passed a direct current of 60 volts through 50-millimeter-thick concrete discs for six hours; ASTM C1202 is a standard test method used to measure electrical conductivity in concrete, enabling one to gauge permeability to calculate the permeability class of each combination according to the charge sent in Coulombs. The charge levels are lower, so that means chloride cannot get in as easily, and the concrete lasts longer.

All the bottom right experiments in Figure 4 show that DNF and GNSA, added to the concrete mix, greatly minimize the chances of chloride affecting the concrete mix. With a maximum charge capacity of 4250 Coulombs, the control mix (composition C1) was able to withstand this level of charge. It indicated that it was highly permeable and in low resistance to chloride entry. In 5% GNSA + 5% DNF with composition C2, the charge sent +++ decreased considerably to 2800C. GNSA has pozzolanic potential, and DNF can occupy small pores, which facilitates this enhancement.

This reduction seems to have improved both pore refinement and the permeability. Among all C4 compositions, that mixed with 10% GNSA for composition C4 had the lowest charge of 2600 Coulombs. This finding indicates that increasing the volume of pozzolanic improves durability more. What composition, C4, found was that it did this. Research shows that incorporating GNSA and DNF into concrete greatly improves its resistance to chloride ion ingress.

As the control mix, composition C1 didn't share any supplementary cementitious components and showed the highest permeability. GNSA is pozzolanic, making concrete stronger by reducing pore connectivity and fine-tuning capillary pores. The blend containing 10% GNSA from composition C1 and producing a minimum charge on passing through was observed in this regard. A 5% GNSA and a 5% DNF of composition C_2 mixture were challenged to pass through the same electrode, and they passed an average charge that was found to be less than that of the control combination by 34%.

This experiment shows how the two sections help each other improve. Such a small permeability increase due to increasing DNF in composition C3 from 5% to 10% can potentially be explained by the uneven distribution of fibers within the matrix (limiting flow), generating some tiny gaps.

The permeability of the composite C5 mixture was considerable, and without pozzolanic ingredients, having only 5% composed of DNF. This shows that fibers alone do not block chloride very well. The outcome indicates that GNSA, along with DNF as an optimal composition, generates chloride exclusion in reinforced concrete constructions and hence its longer life longevity.

3.5. Electrochemical Corrosion Test

GNSA and DNF conducted an investigation to evaluate electrochemical corrosion in concrete samples to determine the potential deterioration of steel reinforcement inside them. The half-cell potential method was used through a saturated calomel electrode, and the extent of corrosion in steel reinforcement present in the concrete matrix was determined. To accelerate the process, samples were subjected to immersion in a 3.5% sodium chloride solution.

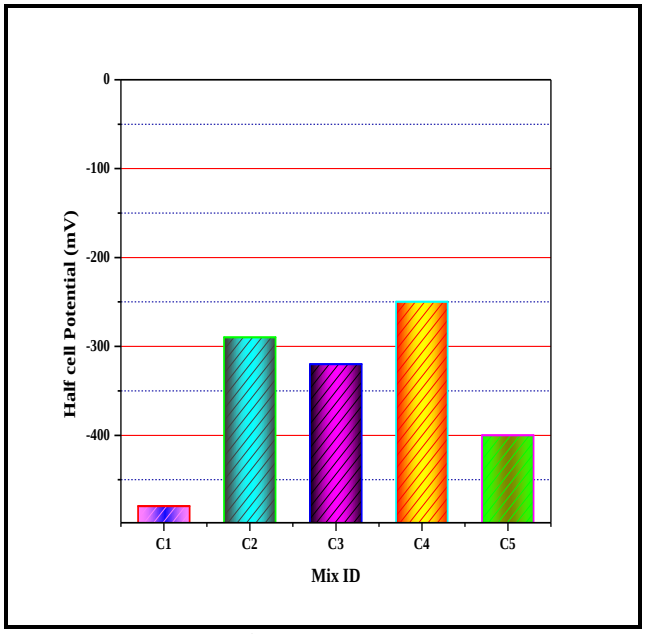

Fig. 5 Results of electrochemical corrosion tests

The experimental results are shown in Figure 5. The results also showed that GNSA- and DNF-based concrete has better corrosion resistivity. The potential of the control mixture (C1) was more negative (-480 mV), indicating a high susceptibility to corrosion. There are no pozzolanic materials in conventional concrete, so it will not get the advantages of pore structure improvements that inhibit chloride fattening [27]. Two compositions, C2, which contained 5% GNSA and 5% DNF, and C4, which had a composition of 10% GNSA and 0% DNF, had the greatest negative potentials of -290 mV and -250 mV, respectively. Composition C2 is less susceptible to rusting than composition C4. The addition of GNSA considerably decreased the porosity of the concrete material, thus stopping moisture and chloride ions from reaching reinforcing materials. In addition, the compositions integrated into the concrete displayed excellent management of microcracks in the structures.

On the other hand, composition C2 of equal ratios between GNSA and DNF had lower negative potential, which is only -320 mV compared to potential -290 mV of composition C3. Adding in more fiber may actually cause it to not spread evenly enough to allow cavities, therefore reducing its effectiveness at protecting. Fibers alone do not protect against corrosion as pozzolanic materials. 28 GNSA, as a promising approach to decreasing corrosion risk by refining pores and reducing permeability, is observed on composition C5, which resulted in 5% DNF and 0% GNSA with a noble potential of -400 mV. Composition C4 was the least susceptible to corrosion and the lowest risk of corrosion potential (-250 mV minimum). Perhaps GNSA removed 10% of the cement, which could explain this improvement. Composition C2, which used GNSA and DNF comixed together, exhibited great results [28]. It also seemed to be indicative that fiber reinforcement may work in conjunction with one another to increase corrosion minimization. Whenever 10% of the DNF quantity was in composition C3, the protecting effect was somewhat lower because this time the fibers were agglutinated, so probably a weakness of the matrix in some places happened. In contrast, the very high corrosion risk of -400 mV for the composition C5 indicated that fibers alone are not effective enough in protecting against chloride penetration. The mix consists of 5% DNF and 0% GNSA.

This result indicates that the ratio of GNSA and DNF in concrete is a key factor in developing more durable concrete, capable of preventing corrosion [29]. Furthermore, the study demonstrates that incorporating GNSA dramatically lowers susceptibility to corrosion in concrete, with alterations in pore structure and declines in permeability as contributing factors. This modification essentially prevents the penetration of chlorine ions and water into the concrete matrix. DNF adds to improving durability, controlling cracking that can be performed with different proportions of DNF according to specifications; however, the benefits and effectiveness are determined by proper additions or compliance in using this additive for construction works. When evaluating the other combinations, the C4 formulation with 10% GNSA and without DNF showed superior performance to be the lowest corrosion potential for reinforcement. Of all the combinations studied, this one exhibited the most negative half-cell potential (-250 mV). However, a large portion of the DNF C3 (10% DNF) showed poor corrosion resistance. This finding suggests that fibers may increase the service life of the materials, but their content should be optimized in respect to mechanical properties and durability. Thus, the findings demonstrate that introducing GNSA and DNF to concrete structures would be environmentally friendly. Under adverse weather conditions, this method will help protect reinforced structures better from corrosion.

4. Environmental Impact Assessments

The environmental impact of the GNSA-DNF concrete was examined in terms of cement reduction and the use of synthetic waste sources. If GNSA replaces some of the cement, it might lower the amount of carbon released in making it. The use of DNF also assists in trash recycling and reduces the quantity of rubbish for disposal. But the overall environmental benefits depend on the processing of ash,

preparation of fibers, transport, and energy use. A comprehensive life-cycle study is rsired to determine the CO_2 emissions and to prove the environmental advantages of the enhanced concrete. CO_2 emissions of each concrete mix in Equation (1).

$$Eco_2 = \sum_{i=1}^{n} miEF_1 \quad (1)$$

Where mi is the quantity of material i in kg per m3, EF1 is its embodied-carbon emission factor in kg CO_2-equivalent per kg of material. The assessment should include transport, processing and use emission factors from an experimental source. It is necessary to compare the control mix and altered mixes on an equal functional basis, preferably 1 m^3 of concrete with predicted performance.

5. Conclusion

This study aimed to quantify the influence of DNF and GNSA on the mechanical properties and service life of concrete. The results show that GNSA could be a pozzolanic material, significantly increasing both the strength and durability of concrete. Therefore, this addition would probably improve the pore structure and decrease permeability. C4 was found to provide optimal compressive strength and corrosion inhibition. Also, this formulation gave the best effectiveness at a GNSA concentration of 10% and without DNF. The formulation helped increase the toughness of DNF, resulting in a more resilient material. Whereas the high fiber load with a specific size has restricted the processability of the composite and resin distribution in the field, it has diverted mechanical properties that could impact its operational performance, along with a reduction in overall strength. But a loss of global strength in both cases and a patchy performance. C4 has a low negative half-cell potential of -250 mV and hence was expected to experience higher corrosion, and these findings correlate with the results observed from the electrochemical corrosion experiment. C3 was 10% DNF (or degradable natural fiber) when it was tested, so it had excellent corrosion prevention. On the other hand, C4 was the worst performer. Using GNSA with the correct quantity of DNF adds an eco-friendly alternative and could improve long-term concrete durability in the field. Therefore, GNSA with the appropriate level of DNF is a beneficial way to build when foul weather sets in. This process strengthens and improves the performance of concrete in demanding environments.

Conflicts of Interest

There is no conflict of interest regarding the publication of this paper.

Funding Statement

No

References

[1] Amin Akhnoukh et al., "Impact of Supplementary Cementitious Materials on Alkali-Silica Reactivity of Concrete," *Proceedings of the Proceedings of 59th Annual Associated Schools of Construction International Conference*, vol. 4, pp. 280-288, 2021. [Google Scholar]

[2] Hamin Eu et al., "Alkali-Silica Reaction and Residual Mechanical Properties of High-Strength Mortar Containing Waste Glass Fine Aggregate and Supplementary Cementitious Materials," *International Journal of Concrete Structures and Materials*, vol. 18, no. 1, pp. 1-20, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[3] Alexey Brykov, Mikhail Voronkov, and Maxim Mokeev, "Ultrafine Silica Additives Behavior during Alkali-Silica Reaction Long-Term Expansion Test," *Open Journal of Civil Engineering*, vol. 5, no. 2, pp. 66-72, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[4] Eloise Aparecida Langaro et al., "Rice Husk ash as Supplementary Cementing Material to Inhibit the Alkali-Silica Reaction: A Review," *Revista IBRACON de Estruturas e Materiais*, vol. 14, no. 4, pp. 1-14, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[5] Veronica Guerini et al., "Influence of Steel and Macro-Synthetic Fibers on Concrete Properties," *Fibers*, vol. 6, no. 3, pp. 1-14, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[6] R. Suresh Premil Kumar et al., "Discarded Multifilament Fishnet/Glass Fiber and Polyester Composites: Tensile and Flexural Behavior," *AIP Conference Proceedings*, vol. 3137, no. 1, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[7] Bravin Daniel Emmanuel et al., "Exploring the Adverse Environmental Effects of Bio Teakwood as Filler in bio-Degradable PU Hybrid: A Sustainable and Systematic Approach," *Matter (Rio de Janeiro)*, vol. 29, no. 4, pp. 1-14, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[8] Athiappan Kamalasekar et al., "Static and Cyclic Behaviour of Fibre-Reinforced Pavement Concrete with Copper Slag as Fine Aggregate," *Matter (Rio de Janeiro)*, vol. 29, no. 1, pp. 1-14, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[9] Kamalasekar Athiappan et al., "Mechanical Properties of Asphalt Mixtures Containing Reclaimed Asphalt Incorporating Acrylonitrile Butadiene Styrene (ABS)," *Matter (Rio de Janeiro)*, vol. 28, no. 4, pp. 1-11, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[10] Vagelis G. Papadakis, "Effect of Supplementary Cementing Materials on Concrete Resistance Against Carbonation and Chloride Ingress," *Cement and Concrete Research*, vol. 30, no. 2, pp. 291-299, 2000. [CrossRef] [Google Scholar] [Publisher Link]

[11] Michael Thomas, "The Effect of Supplementary Cementing Materials on Alkali-Silica Reaction: A Review," *Cement and Concrete Research*, vol. 41, no. 12, pp. 1224-1231, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[12] Medhat H Shehata, and Michael D. A Thomas, "Use of Ternary Blends Containing Silica Fume and Fly ash to Suppress Expansion due to Alkali-Silica Reaction in Concrete," *Cement and Concrete Research*, vol. 32, no. 3, pp. 341-349, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[13] J.A. Ajayi, "Mitigation of Alkali- Silica Reactions in Concrete Pavements using Supplementary Cementitious Materials," *Materials Today: Proceedings*, vol. 86, pp. 59-66, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[14] Peng Shi et al., "Investigation on the Anti-Carbonation Properties of Alkali-Activated Slag Concrete: Effect of Activator Types and Dosages," *Journal of Building Engineering*, vol. 91, pp. 1-12, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[15] Hengyu Liu et al., "Experimental Investigation on Early-Stage Performance and Carbonation Resistance of Na_2CO_3-$CA(OH)_2$ Activated Slag," *Construction and Building Materials*, vol. 504, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[16] Yun Chen, Qianwang Fu, and Wenbo Zheng, "NGBoost-based Prediction of Carbonation in Alkali-Activated Slag Concrete Enhanced by Metaheuristic Algorithms," *Construction and Building Materials*, vol. 500, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[17] Dapeng Zheng et al., "CO_2-Mineralization Strategy and Mechanism of Alkali-Activated Slag Paste," *Construction and Building Materials*, vol. 463, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[18] Laura Diaz Caselles et al., "Carbonation of Alkali-Activated Materials: Changes in Mineralogical Composition and pH, and Qualitative Estimation of Corrosion Risk," *Materials and Structures*, vol. 58, no. 4, pp. 1-21, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[19] Mariana Perardt et al., "Improving the Carbonation Resistance of Alkali-Activated Slag Containing Mineral Additions: Investigation under Natural and Accelerated Conditions," *Journal of Materials in Civil Engineering*, vol. 37, no. 2, 2025. [CrossRef] [Google Scholar] [Publisher Link]

[20] Joonho Seo et al., "Exploring Natural and Accelerated Carbonation of Alkali-Activated Slag," *Construction and Building Materials*, vol. 432, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[21] Patrick Azar et al., "Effect of Natural and Accelerated Carbonation on Microstructure and pH of Sodium Carbonate Alkali-Activated Slag," *Cement and Concrete Research*, vol. 181, pp. 1-14, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[22] Amir Ramezani et al., "Experimental and Thermodynamic Investigating of Carbonation Behavior in Alkali-Activated Slag-Calcined Clay Materials with Different Binder Constituent," *Construction and Building Materials*, vol. 446, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[23] Patrick Azar "Durability of Sodium Carbonate Alkali-Activated Slag Concrete Assessed by a Performance-based Approach," *Construction and Building Materials*, vol. 423, pp. 1-18, 2024. [CrossRef] [Google Scholar] [Publisher Link]

[24] Solmoi Park et al., "Thermodynamic Modeling and Experimental Study of Carbonation of Alkali-Activated Slag Cements," *ACS Sustainable Chemistry and Engineering*, vol. 11, no. 10, pp. 1-55, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[25] Rongsheng Xu et al., "Improving the Carbonation Resistance of Alkali-Activated Slag Mortars with Different Additives: Experimental Evaluations," *Construction and Building Materials*, vol. 366, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[26] Ghandy Lamaa et al., "Carbonation of Alkali-Activated Materials: A Review," *Materials*, vol. 16, no. 8, pp. 1-18, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[27] Gregor J.G. Gluth et al., "Carbonation Rate of Alkali-Activated Concretes and High-Volume SCM Concretes: A Literature data Analysis by RILEM TC 281-CCC," *Materials and Structures*, vol. 55, no. 8, pp. 1-15, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[28] Eric R. McCaslin, and Claire E. White, "A Parametric Study of Accelerated Carbonation in Alkali-Activated Slag," *Cement and Concrete Research*, vol. 145, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[29] Maher Al-Jabari et al., "Mitigation of Alkali Silica Reactions in Concrete using Multi-Crystalline Intermixed Waterproofing Materials," *Cement*, vol. 12, pp. 1-9, 2023. [CrossRef] [Google Scholar] [Publisher Link]