

RESEARCH ARTICLE

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DURABILITY PROPERTIES OF CONCRETE BY PARTIAL REPLACEMENT OF FINE AGGREGATE AND COARSE AGGREGATE BY ALCCOFINE AND GLASS POWDER

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ABSTRACT

This study's objective is to assess the high performance of concrete (HPC) that contains additional cementitious materials such as Alccofine, Nano clay and glass powder. Due to demands in the building sector, high-performance concrete is becoming more and more necessary. Concrete's strength and durability can be enhanced by using cement substitutes in conjunction with chemical and mineral admixtures, according to recent efforts to improve the material's performance. Nano clay improves concrete's mechanical characteristics, durability, and fracture resistance by increasing particle packing and decreasing porosity. It also improves workability, strength, and water retention in concrete, making it more durable and permanent. Alccofine are pozzolanic materials that can be used to create concrete composites that are incredibly robust. Glass is not biodegradable, and landfills are not an environmentally beneficial option because it takes a very long time for these materials to break down. Thus, there is a compelling need to use glass waste. The mechanical and durability of a mix of concrete that contains glass powder, Nano clay and Alccofine is examined in this study. 5, 10, 15, 20, 25, and 30% are used in place of the alccofine, 5, 10, 15, 20, 25 is used in place of the Nano clay and 10, 20, 30, 40, and 50% are used in place of the glass powder. The performance of concrete mixtures is examined in this study using tests for Compressive strength test, Flexural strength test, Tensile strength test, water absorption, Sorptivity, acid and sulphate attacks, marine environments test, and rapid chloride penetration test at periods 28 and 56 and 90 days. The findings show that adding leftover glass powder to concrete improved its workability and compressive strength, while adding Alccofine increased its durability and decreased the diffusion of chloride.



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I. INTRODUCTION

Gavrilitea [1] analysed the influencing factors for the sand market and reviewed the impacts caused due to mining. To study the impact of sand mining, different database sources were used. The study reported that there is a global imbalance in the supply and demand of the sand market. Sand is utilized in various industries, such as chemical, ceramic, foundry, glass making, recreational products and construction, in which the construction industry consumes a major share. The study concluded that the mining of sand produces various impacts such as loss of habitat vegetation, increase in turbidity of river water and bank erosion over the environment. The study recommended finding substitutes for sand such as recycled aggregate, crushed sand, quarry dust and glass waste. Ashraf et al. [2] investigated both negative and positive impacts of sand mining in rivers of Selangor state. The study focused on sediment transport, sampling, sediment grain size distribution and water column. In addition,

Hydrologic Engineering Cantera River Analysis System (HEC-RAS) was carried out to perform one-dimensional hydraulic calculations for sediment and transport. The study revealed that sand mining affected all activities linked with the environment, particularly turbidity and quality of water, habitat, flora and fauna, groundwater table, stability of structures and biological environment. The study suggested various mitigating measures for sand mining and concluded that sand mining should be avoided to safeguard the environment. The study also recommended using the substitute for river sand, such as crushed stone and recycled aggregates. Park et al. [3] Crushed waste glass was tested as a substitute for river sand in concrete. Waste glass was replaced for river sand in amounts ranging from 0 to 70%. The workability, air content, compressive, tensile, and flexural strength of concrete specimens were all examined in this study. The study found that using 70% glass powder resulted in a 44.3 percent loss in workability and a 40% rise in air content. The investigation revealed that using glass powder resulted in a significant drop in mechanical characteristics. With the use of glass powder, compressive strength was lowered by almost 90%. The study claimed that the considerable decrease in the mechanical properties with the utilization of glass powder was due to the poor bond between glass powder and the matrix.

The study concluded that utilization of glass powder in the place of river sand reduced the mechanical properties of the concrete. Shi et al. [4] Have studied the properties and pozzolanic reactivity of glass particles. The study assessed and compared the particle shape, fineness, and pozzolanic reactivity of glass powders derived from several sources (GP-fine, GP-dust, GP4000, and GP-6000) for use as cement alternatives. Compared to fly ash, glass powder has higher quantities of SiO_2 , CaO , and Na_2O but significantly less of Al_2O_3 . The study's findings suggested that substituting cement made from Portland cement by glass powder might lower the amount of Alkali Aggregates Reaction (AAR)-induced expansion. The pozzolanic activity of finely crushed glass particles was discovered to be quite high. The study findings also revealed that the pozzolanic reaction happens at a later age in GPC due to the high SiO_2 content. An investigation on the impact of fine glass powder on concrete durability was conducted by Schwarz et al. [5]. To determine the durability qualities of cement, 10% of the cement is substituted with glass powder (GP). The study discovered that using glass powder as a cement substitute material reduces expansion produced by the alkali-silica reaction in concrete. The chloride penetrability data indicate that there has been some pore refining in the sample.

The 28-day compressive strengths of concretes prepared with 10% glass powder as substituting cement were found to be higher than those of fly ash concrete. Finally, the research found that fine glass powder improves the durability of concrete mixes. Bhupendra Singh shekhawat [6] Glass garbage represents one of the environmental problems. Every industry has seen a significant increase in the use of glass, which has essentially led to a rise in trash disposal. Glass garbage is also regarded as a non-biodegradable substance that contaminates the environment. The necessity to reduce energy use has grown as a result of global warming. It is widely acknowledged that the effects of global gasses have affected every person on the world. Cement production requires a lot of energy, which adds to greenhouse gas emissions and releases a lot of carbon dioxide (CO_2). Over the previous 200 years, atmospheric carbon dioxide levels have increased by almost 30%. Because waste materials do not negatively impact the short-term or long-term qualities of concrete and provide a platform for their efficient disposal, their usage in building projects has increased significantly in recent years. One such substance is leftover glass powder [7]. Only with the introduction of steel reinforcing did Portland cement's use in the concrete industry become widely used. Cement manufacture on a wide scale is contributing to both environmental issues and the unchecked loss of natural resources.

Given that concrete is one of the most widely utilized building materials after water, the cement sector is accountable for around 5% of global CO_2 emissions. Every year, millions of tons of glass garbage are produced worldwide. Sunny et al. [8] Investigated the viability of replacing some of the cement in cementitious systems with waste glass. One of the biggest waste streams is garbage from construction and demolition. It is now generally acknowledged that, in order to optimize both economic and environmental benefits, there is a substantial potential for reclaiming and recycling demolished material for use in value-added applications. Sand, limestone, and various other raw materials must be mined before cement can be produced, which consumes a lot of energy and raw resources [9]. Clinker, the major component of cement, is formed when the raw ingredients are crushed, mixed, and then destroyed at 1450°C . The high temperature of cement kilns is required for the clinker's production. A variety of fuels, including fuel oil, petroleum coke, mineral coal, diesel, natural gas, and used fuels such as waste as well as biomass, are available for this purpose. The cement industry is a cause of environmental issues due to the significant volumes of cement produced and the enormous resource usage.

The major causes of this scenario are excessive carbon dioxide (CO_2) emissions from fossil fuel combustion and carbon reduction of limestone as part of the clinker-making processes. Furthermore, the biggest environmental hazard of the twenty-first century is climate change and global warming brought on by increased levels of anthropogenic CO_2 emissions into the atmosphere. K. Gayathri [10] Achieving strength properties is not the only need for producing high-quality concrete in the current climate. One of the key requirements for getting high-quality concrete is increasing its durability, lowering its porosity to last longer, and creating green concrete. Concrete's compressive strength is crucial due to its primary characteristics. Since it is simple to execute and the majority of the desirable characteristics of concrete are qualitatively connected to its compressive strength, the compressive test is the most often performed test on hardened concrete. This study examines the impact of replacing ultra-fine slag (Alccofine) on the mechanical characteristics of high-strength concrete. It has been discovered that adding ultrafine slag to concrete increases its workability and fluidity in addition to its compressive strength. Additionally, it increases the durability and dependability of reinforced concrete buildings and exhibits resistance to segregation.

D. Sharma, S. Sharma and Ajay. G [11] investigated experimentally how concrete's strength may be increased by using Alccofine for cement and foundry slag for traditional fine aggregate. They came to the conclusion that replacing cement with 15% Alccofine and fine aggregate with 10% to 45% foundry slag may result in concrete with a respectably high strength. M.V. Sekhar Reddy, K. A. Latha and k. Surendra [12] has conducted experiments on partially substituting fly ash and Alccofine for cement in M40 Grade concrete at percentages of 5%, 10%, 15%, and 20%. Alccofine's addition shows an early strength-gaining potential and is environmentally benign, according to the findings. In terms of long-term strength properties, alccofine performed better than fly ash. Swar shah [13] the most popular material in the building sector right now is Portland cement. It is made by heating materials in a kiln to a fine powder. Its chemical makeup is mostly composed of silicates and aluminates. Portland Cement Concrete is created by combining this cement with water, sand, and aggregates.

These days, the building industry uses this concrete since it is even less expensive than water. According to environmental statistics, about one ton of CO₂ is generated during the production of one ton of cement, which is bad from an environmental perspective. Numerous research has been conducted in an effort to develop alternatives to Portland cement and limit its use. According to the investigations, fly ash, slag, rice husk, and met kaolin as Pozzolanic Materials to partially replace the cement. Sheethal Sasikumar [14] Biochar is the lightweight, ash-and-carbon-based substance that is left over when biomass is pyrolyzed. the elimination of vibrating machinery, less noise, fewer air gaps, shorter turnaround times, increased output, and improved robustness and longevity. Two crucial elements of SCC are the particle size and the quantity of powder content. More cement in SCC would increase manufacturing costs. Many academics have suggested alternative supplemental cementitious materials (SCMs) or mineral admixtures to achieve higher economic value in light of quickly growing businesses. A high range water reducer called Alccofine 1203 makes concrete easier to work with and increases its compressive strength. Many people believe that biochar is an efficient method of storing carbon dioxide. The potential for using it to decrease permeability and increase mechanical strength of cement mortar is explored in this study.

Yatin Patel [15] The excessive focus on concrete's compressive strength rather than its performance requirements is one of the primary causes of concrete's historical degradation. When reinforced concrete constructions deteriorate, hostile chemicals from the environment are often transported, followed by chemical and physical reactions in the inside of the structure. Concrete's permeability properties determine how aggressive gasses and/or liquids are transported through it. Concrete's durability performance, as measured by physio-chemical deterioration, rises as its penetration decreases. As a result, one of the most important factors in determining how long concrete will last in harsh settings is its penetration. Srushti P [16] Cement is the most significant building material now, and it is expected to remain so in the future. The construction materials must meet new and higher demands, and in order to do so, the materials must not only have good strength properties but also be durable enough to last for a longer period of time, thus improving the durability of the concrete and producing a greener concrete, which are now becoming important criteria in obtaining high-quality concrete. The goal is to improve the performance and durability of concrete by partially substituting cement with naturally occurring industrial wastes or by-products that need less energy.

Some of these chemical and industrial byproducts, such as Alccofine, have recently received attention for their potential applications. The utilization of these extra ingredients to produce high-performance concrete is a relatively recent strategy. The current study focuses on the durability properties of M30 grade concrete with partial cement substitution with varying concentrations of Alccofine. Aseel Mansi. [17] Nano clay has been widely discussed for its potential to enhance construction materials and technical applications. This review article examines the impact of nano clay as a cement substitute and supplement on the performance of conventional and high-performance concrete. Adding nano clay to high-performance concrete improved compressive and flexural strength, durability, and resistance to sulfate attack. It also reduced porosity, permeability, and water absorption. Nano clay enhances material properties by acting as reinforcements, fillers, nucleation sites, and reactive pozzolans, promoting hydration. Nehal Hamed, [18] the use of nano-clay (5, 7.5, and 10%) as partial cement replacements in two ways: as received and after dispersion in water using a bath sonicator. The examination was based on compressive strength, split tensile strength, flexural strength, and sliding bond. SEM, XRD, and AFM were used to verify the strength and split bond strength of nano-clay concrete, as well as its microstructure characterization.

Sonication of nano-clay particles greatly improved the characteristics of concrete compared to the original material. The optimal percentage of cement substitution by nano-clay was discovered to be 7.5% among as-received and vibrated nano-clay. The inclusion of NC particles resulted in a thick and well-compacted matrix compared to the control mix, as seen by micrographs from SEM, XRD, and AFM data. Sonicated NC also demonstrated increased reactivity compared to as-received NC. Jamal A. Abdalla [19] For decades, researchers have attempted to enhance the durability of concrete by including more cementitious elements. Nanomaterials can enhance the mechanical and durability qualities of concrete, according to recent breakthroughs in the sector. This study presents a detailed overview of recent advances in the use of nanomaterials as a performance enhancer in cement/geopolymer concrete. The study found strong relationships between cementitious matrices reinforced with nano-TiO₂, nano-Fe₂O₃, nanoclay/metakaolin, and nano-CaCO₃. Fresh qualities, microstructure, mechanical and durability characteristics, and the effect of different particle sizes have all been examined. Estefania Baigorria [20] analyzed the CO₂ effect of various industries and especially compared CO₂ emissions to the cement industry.

According to the World Resources Institute (WRI), the cement sector accounts for 3.8% of total greenhouse gas (GHG) emissions and around 5% of world CO₂ emissions. The primary source of CO₂ in cement production is the heating of raw materials in a rotating kiln. The study concluded that the cement sector releases more CO₂ into the environment when producing cement than other businesses. To minimize CO₂ emissions in the environment, this study advises using alternate fuels and biomass in clinker manufacture, as well as improving energy efficiency and clinker replacement. A viable alternative to clinker will be a new kind of clinker. A promising alternative for clinker will be a new class of clinker Be Lite-Calcium Sulfuric aluminate-ferrite. The climatic change due to the cement industry is studied by McCaffrey [21] It has been reported that cement output increases by 3% per year. The cement industry is responsible for four significant emissions: dust, Sulphur, NO_x, and carbon dioxide. The first three are not substantial contributors to global warming. CO₂ emissions are the primary cause of global warming, and the worldwide cement sector produces 1.4 billion tons of CO₂ per year. The cement sector accounts about 6% of CO₂ emissions and approximately 4% of global warming.

As a result, the study recommends slag, fly ash, and limestone as an alternative to calcined material in cement that is less expensive and emits less (or no) greenhouse gases. Gavriltea [22] analyzed the influencing factors for the sand market and reviewed the impacts caused due to mining. To study the impact of sand mining, different database sources were used. The study reported that there is a global imbalance in the supply and demand of the sand market. Sand is utilized in various industries, such as chemical, ceramic, foundry, glass making, recreational products and construction, in which the construction industry consumes a major share. The study concluded that the mining of sand produces various impacts such as loss of habitat vegetation, increase in turbidity of river water and bank erosion over the environment. The study recommended finding substitutes for sand such as recycled aggregate, crushed sand, quarry dust and glass waste. Shi et al. [23] have analyzed the characteristics and pozzolonic reactivity of glass powders. The study evaluated and compared the particle shape, fineness, and pozzolonic reactivity of glass powders from various sources (GP-fine, GP-dust, GP- 4000, and GP-6000) for usage as cement substitutes.

Compared to Fly ash, the chemical composition of glass powder contains larger levels of SiO₂, CaO, and Na₂O but much lower levels of Al₂O₃. The study result concluded that replacing Portland cement with glass powder may reduce the amount of Alkali Aggregates Reaction (AAR)-induced expansion. The pozzolnic activity of finely crushed glass particles was found to be high. The study results also indicated that the pozzolonic reaction occurs at a later age GPC because of the high SiO₂ concentration. An investigation on the impact of fine glass powder on concrete durability was conducted by Schwarz et al. [24]. For the purpose of determining durability properties in cement, 10 percent of the cement is substituted with glass powder (GP). The study found that the utilization of glass powder as a cement replacement material can minimize expansion caused by the alkali-silica reaction in concrete. The chloride penetrability results show that there has been some degree of pore refinement in the sample.

II. MATERIAL PROPERTIES

II.1 WASTE GLASS POWDER:

In this work, waste glass powder (WGP) is used as a partial substitution for GGBS in GPC. The chemical structure of XRF was determined by analysing WGP particles. According to the chemical makeup of WGP, the majority of the material is SiO₂, accounting for around 69%. WGP has a specific gravity of 2.62 and a specific area of 463 m²/kg. The unit weight of WGP is 2580 kg/m³. Figure 1 demonstrates that the WGP used in this inquiry is an irregular in shape. The picture of WGP was used in this work



Figure 1: (a) Waste Glass powder (b) Waste Glass powder SEM Analysis.

Source: Authors, (2026).

Table 1: Chemical composition of WGP.

S. No	Constituents	Percentage Composition (%)
1.	Al ₂ O ₃	3.20
2.	Fe ₂ O ₃	0.65
3.	CaO	9.85
4.	K ₂ O	0.84
5.	Na ₂ O	10.11
6.	SiO ₂	71.80
7.	MgO	3.2
8.	Loss of Ignition	0.35

Source: Authors, (2026).

II.2 NANO CLAY:

Concrete performs much better when nano clay is added because it increases workability, strength, and durability. By improving the microstructure and decreasing porosity, it increases compressive and flexural strength and increases the concrete's resistance to environmental assaults such sulfates and freeze-thaw cycles as well as water penetration. Additionally, nano clay reduces shrinkage and cracking, enhancing the mix's overall cohesiveness. It also speeds up cement hydration, which results in a quicker development of early strength, and improves workability without raising water demand. One of its environmentally beneficial effects is that it uses less cement, which lowers carbon emissions. Additionally, by enhancing thermal stability, nano clay increases concrete's resistance to exposure to high temperatures and fire. Nano clay is a useful addition for improving the sustainability and performance of concrete constructions because of these benefits.



Figure 2: Nano clay powder.

Source: Authors, (2026).

Table 2: Chemical composition of Nano clay.

S. No	Constituents	Percentage Composition (%)
1.	SiO ₂	57.5
2.	Al ₂ O ₃	23
3.	MgO	6
4.	Fe ₂ O ₃	2.5
5.	CaO	1.5
6.	Na ₂ O	4
7.	K ₂ O	2
8.	TiO ₂	3.5

Source: Authors, (2026).

II.3 ALCCOFINE 1203:

ALCCOFINE 1203 has a distinct chemical composition consisting mostly of CaO 30-34% and SiO₂ 30-36%, as seen by the chemical composition and physical features given below. Physically, the product is unusual in terms of particle size distribution.



Figure 3: (a) Alccofine Normal View (b) SEM Analysis.

Source: Authors, (2026).

Table 3: Chemical composition of Alccofine.

Chemical analysis	Mass %
CaO	35
Al ₂ O ₃	20.1
Fe ₂ O ₃	3.1
SO ₃	0.5
MgO	7.3
SiO ₂	36

Source: Authors, (2026).

II.4 FINE AGGREGATE:

Aggregate is a coarse to medium grained particulate substance used in concrete building. The aggregate phase provides mechanical strength to the structure while also influencing the fundamental qualities of concrete, such as strength, unit weight, Young's modulus, workability and durability. Fine aggregate with a high void-filling capability aids in the production of dense concrete with maximum strength and extends the structural durability. This operation employed manufactured sand (M-sand) as the fine aggregate. The M-sand utilized in this experiment was acquired locally by crushing stone. M-sand has a cubical form, rounded corners, and a dimension of less than 4.75 mm. The physical properties of M-sand are tabulated in Table 4. Properties of the M-sand are determined as per IS: 2386 – 1963 [138], and the values are confirmed to IS: 383- 1970.

Table 4: Physical properties of M-sand.

S. No	Physical Property	Value
1.	Specific gravity	2.62
2.	Fineness Modulus	2.36
3.	Zone	III
4.	Bulk density	1702m ³

Source: Authors, (2026).

II.5 COARSE AGGREGATE:

Coarse aggregate accounts for the majority of the concrete's volume and strength. Because of the weathering activity of the rock, coarse aggregate derived from its core half is desirable. The physical qualities of aggregate, such as specific gravity, hardness, and texture, vary depending on where it is extracted. Aggregates can be smooth, spherical, or angular (crushed stones). Typical coarse aggregate sizes vary from 4.7 to 20 mm.

For this project, coarse aggregate (CA) was purchased from a local quarry. The coarse aggregate utilized in this work has an angular form and is clean and dry. The physical properties of coarse aggregate are tabulated in The Properties of the coarse aggregates are confirmed to IS: 383-1970.

Table 5: Physical properties of Coarse Aggregate.

S. No	Physical Property	Value
1.	Specific gravity	2.67
2.	Fineness Modulus	6.10
3.	Zone	1456 m ³

Source: Authors, (2026).

II.6 MIXING, CASTING AND CURING OF CONCRETE:

The components for the mixes (AF and cement, WGP and M-Sand) were weighed and mixed dry for 3-4 minutes before adding coarse aggregate. The alkaline liquid, a mixture of sodium hydroxide and sodium silicate solutions, was then added to the dry mix and stirred for 3-5 minutes before adding some more water, around 20% of the binder's weight, to increase workability. The mixing was continued for approximately 6-8 minutes. After mixing, the concrete was poured in conventional steel Molds and compacted properly. Precautions were made to ensure that the components mixed uniformly. For ambient curing, the cubes were maintained at room temperature after casting, demoulded after one day, and cured at room temperature until testing. Ambient cured specimens are stored in the laboratory at room temperature (27-31°C).

II.7 CEMENT:

The cement utilized in every specimen was standard Portland. Cement grade 53, as per IS: 12269:2013, was used.

II.8 WATER:

The investigation uses conventional potable water from the laboratory supply source.

II.9 CONCRETE:

The cement used is Portland Cement 53 Grade. The cement tests are carried out in compliance with the IS 1489 parameters. Aggregate must be no greater than 20mm, with fine aggregate ranging from 0 to 4.75mm in size. To maintain its intrinsic properties, such as compressive strength, the concrete must be allowed to cure in real-world conditions for around 28 days. A concrete cube (100mm x 100mm x 100mm) is loaded with axial forces in order to evaluate its strength.

III. MIX PROPORTIONS

Table 6: Concrete Mix ID's.

S. No	Mix ID	Description
1.	CM (Conventional Mix)	Fine Aggregate, Coarse Aggregate & Cement
2.	5% of AF	Fine Aggregate replaced with AF for about 5% of its total volume
3.	10% of AF	Fine Aggregate replaced with AF for about 10% of its total volume
4.	15% of AF	Fine Aggregate replaced with AF for about 15% of its total volume
5.	20% of AF	Fine Aggregate replaced with AF for about 20% of its total volume
6.	25% of AF	Fine Aggregate replaced with AF for about 25% of its total volume
7.	5% of NC	Cement replaced with NC for about 5% of its total volume
8.	10% of NC	Cement replaced with NC for about 10% of its total volume
9.	15% of NC	Cement replaced with NC for about 15% of its total volume
10.	20% of NC	Cement replaced with NC for about 20% of its total volume
11.	25% of NC	Cement replaced with NC for about 25% of its total volume
12.	10% of GP	Fine Aggregate replaced with GP for about 5% of its total volume
13.	20% of GP	Fine Aggregate replaced with GP for about 10% of its total volume
14.	30% of GP	Fine Aggregate replaced with GP for about 15% of its total volume
15.	40% of GP	Fine Aggregate replaced with GP for about 20% of its total volume
16.	50% of GP	Fine Aggregate replaced with GP for about 25% of its total volume

Source: Authors, (2026).

IV. EXPERIMENTAL INVERSICATION (MECHANICAL & DURABILITY PROPERTIES)

IV.1 COMPRESSIVE STRENGTH:

Compressive strength was tested as per IS 516 (1959) for the specimens casted with varying mix proportions. It was observed that the compressive strength of 20AF is increased by 0.2 % and 3.15 % when compared to conventional concrete mix tested at 7 days and 28 days respectively. When comparing the results obtained at 28 days, it was found that 20 AF mix recorded the highest compressive strength than other mixes.

IV.2 SPLITTING TENSILE STRENGTH:

Tensile strength was measured in accordance with IS 516 (1959) for specimens cast with varied mix proportions. The tensile strength of 20AF was found to be 32.12% higher than that of normal concrete mix after 28 days of testing. When the findings were compared after 28 days, it was observed that the 20 AF mix had the highest tensile strength of the mixtures tested.

IV.3 FLEXURAL STRENGTH:

The specimens cast with different mix proportions had their flexural strength evaluated in accordance with IS 516 (1959). Compared to a typical concrete mix tested at 28 days, respectively, the flexural strength of 20AF was found to be 9.90% percent higher. In contrast to other mixes, the 20 AF mix had the maximum flexural strength when the results were compared at 28 days.

Table 7: Compressive, Splitting tensile & Flexural test.

S. No	Mix ID	COMPRESSIVE			SPLITTING TENSILE	FLEXURAL
		7 Days	14 Days	28 Days	28 Days	28 Days
1.	CM	26.97	36.07	40.54	3.02	4.04
2.	5 % AF	24.54	33.41	38.21	1.89	2.08
3.	10% AF	25.72	35.11	39.96	2.07	2.91
4.	15 %AF	25.92	36.56	40.56	2.86	3.11
5.	20% AF	27.09	37.12	41.86	3.99	4.44
6.	25 %AF	26.28	35.16	40.49	2.55	3.01
7.	5% NC	25.14	35.89	39.01	2.15	2.98
8.	10%NC	26.66	36.44	40.10	2.99	3.91
9.	15%NC	27.03	37.06	40.99	3.05	4.55
10.	20%NC	25.11	35.21	38.12	2.11	3.65
11.	25%NC	25.03	34.84	37.89	1.89	2.33
12.	10% GP	25.52	36.12	38.37	2.31	3.12
13.	20% GP	26.21	37.56	39.01	2.65	3.88
14.	30% GP	27.56	38.23	40.81	3.56	4.33
15.	40% GP	25.11	36.89	38.36	2.55	3.12
16.	50% GP	24.86	36.01	37.98	2.22	2.97

Source: Authors, (2026).

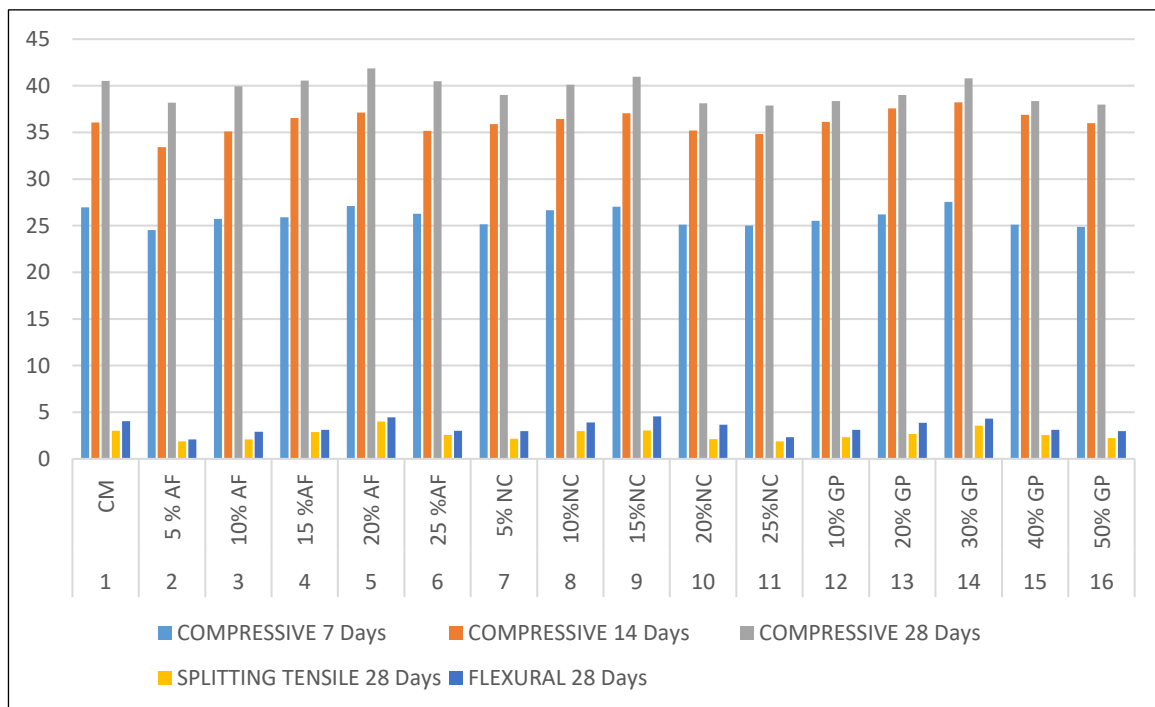


Figure 4: Compressive, Splitting tensile & Flexural test.

Source: Authors, (2026).

IV.4 WATER ABSORPTION:

The water absorption reduction in Saturated stages when cement is replaced by 20 percentage Alccofine and 15 percentage of nano clay when tested at 28,58 and 90 days respectively, with normal conventional concrete. When Glass Powder is used for replacing the fine aggregate by 30%, the reduction in water absorption is 20.5%,21.08%,19.33%.

Table 8: Water absorption test.

Mix ID	28 Days		56 Days		90 Days	
	Initial WA %	Saturated WA %	Initial WA %	Saturated WA %	Initial WA %	Saturated WA %
CM	3.2	4.1	3.14	4.02	3.02	3.89
5 % AF	3.14	3.8	3.08	3.74	2.94	3.61
10% AF	2.98	3.75	2.9	3.62	2.78	3.51
15 % AF	2.95	3.6	2.86	3.54	2.61	3.48
20% AF	2.72	3.4	2.65	3.32	2.52	3.26
25 % AF	3.15	4.2	3.4	4.1	3.24	4.98
5% NC	2.9	3.58	2.72	3.5	2.68	3.4
10% NC	3.1	3.9	3.02	3.52	2.94	3.74
15% NC	3.75	4.23	3.52	4.13	3.40	3.82
20% NC	3.24	3.88	3.18	3.19	3.08	3.02
25% NC	3.09	3.34	3.61	4.06	3.11	3.29
10% GP	2.22	3.5	2.54	2.72	2.03	2.42
20% GP	2.86	3.9	2.65	3.18	2.4	3.08
30% GP	3.92	4.3	3.65	4.12	3.13	4.42
40% GP	3.01	3.44	2.56	3.22	2.68	2.22
50% GP	2.88	3.56	2.98	2.73	2.59	2.09

Source: Authors, (2026).

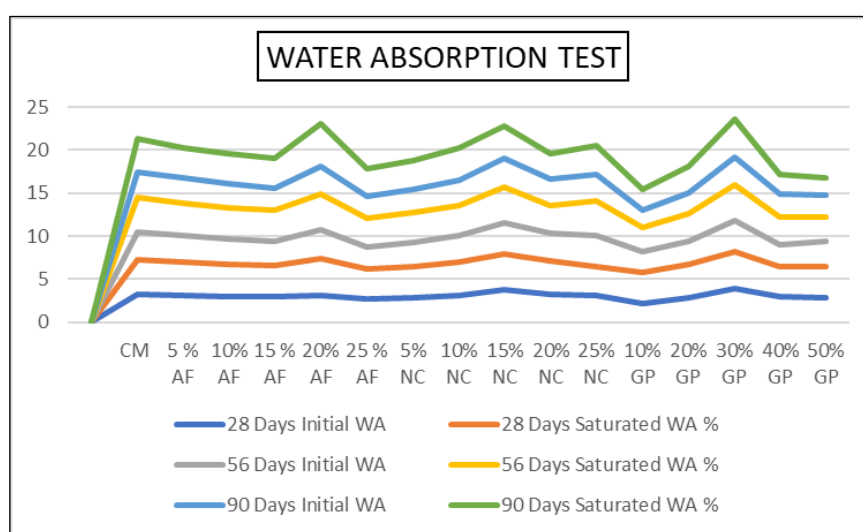


Figure 5: Water absorption test.

Source: Authors, (2026).

IV.5 SORPTIVITY:

The Sorptivity reduction when cement is replaced by 20 percentage Alccofine 15% of nano clay when tested at 60min,90min,120min respectively, with normal conventional concrete. When GP is used for replacing the cement by 30%, the reduction in water absorption is 21.05%, 36.11%, 36.76% with normal conventional concrete.

Table 9: Sorptivity test.

Mix ID	Sorptivity $S = I/T^{0.5}$				
	15 min	30 min	60 min	90 min	120 min
CM	0.138	0.111	0.092	0.098	0.093
5 % AF	0.125	0.104	0.085	0.092	0.081
10% AF	0.092	0.086	0.074	0.077	0.068
15 % AF	0.085	0.072	0.064	0.067	0.059
20% AF	0.092	0.083	0.076	0.072	0.068
25 % AF	0.072	0.062	0.052	0.051	0.044
5% NC	0.033	0.067	0.055	0.055	0.047
10% NC	0.086	0.100	0.083	0.081	0.066
15% NC	0.108	0.095	0.078	0.089	0.072
20% NC	0.101	0.088	0.065	0.075	0.066
25% NC	0.095	0.076	0.062	0.065	0.058
10% GP	0.082	0.069	0.060	0.059	0.051
20% GP	0.072	0.075	0.075	0.080	0.078
30% GP	0.068	0.086	0.089	0.097	0.092
40% GP	0.044	0.058	0.067	0.069	0.071
50% GP	0.032	0.046	0.055	0.042	0.058

Source: Authors, (2026).

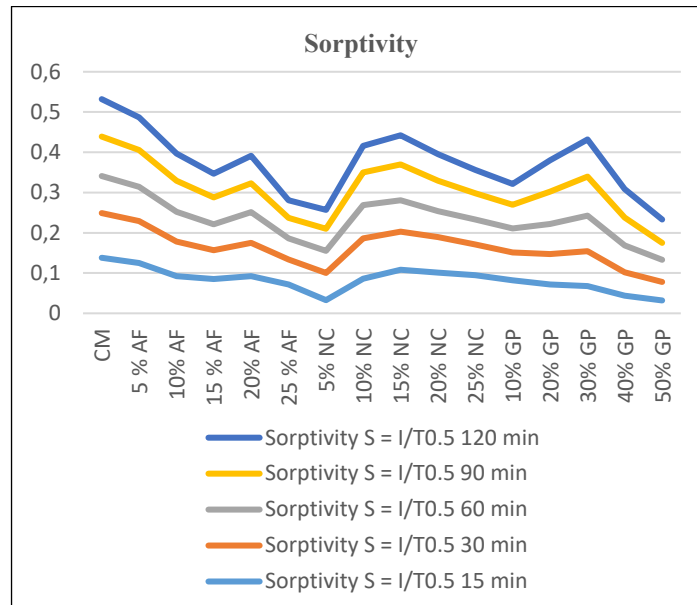


Figure 6: Sorptivity test results.
Source: Authors, (2026).

IV.6. RAPID CHLORIDE PENETRATION TEST (RCPT):

The penetration value is also reduced to 1865, 1875 and 1870 in 20%AF, 15% NC and 30% GP when compared normal conventional concrete.

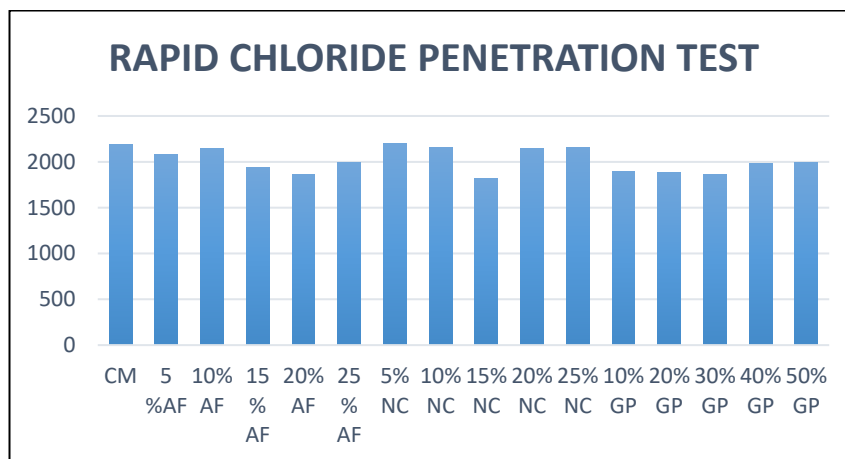


Figure 7: Rapid chloride penetration test.
Source: Authors, (2026).

Table 10: Rapid Chloride Penetration test

Mix ID	Charge Passed C	Standard as per ASTM C1202-2012
CM	2185	Moderate
5 %AF	2085	Moderate
10% AF	2140	Moderate
15 % AF	1940	Low
20% AF	1865	Low
25 % AF	1990	Low
5% NC	2195	Moderate
10% NC	2160	Moderate
15% NC	1820	Low
20% NC	2150	Moderate
25% NC	2160	Moderate
10% GP	1895	Low
20% GP	1880	Low
30% GP	1860	Low
40% GP	1980	Moderate
50% GP	1990	Moderate

Source: Authors, (2026).

IV.7 ACID RESISTANCE TEST HCL:

When AF is substituted with cement, the largest percentage reduction in weight loss is 108.05%, 61.30%, and 62.92% compared to standard concrete for 28, 56, and 90, respectively. When NC is substituted with cement, the largest percentage reduction in weight loss is 77.45%, 73.1%, and 80% compared to standard concrete for 28, 56, and 90, respectively. When GF is substituted with fine aggregate, the greatest percentage reduction in weight loss absorption is 41.9%, 42.3%, and 49.4% compared to standard concrete for 28, 56, and 90, respectively. The largest percentage reduction in strength loss when AF is substituted with cement is 6.54%, 7.23%, and 9.12% when compared to standard concrete for 28, 56, and 90, respectively. The largest percentage reduction in strength loss when AF is substituted with cement is 6.54%, 7.23%, and 9.12% when compared to standard concrete for 28, 56, and 90, respectively. When NC is substituted with fine aggregate, the highest percentage reduction in strength loss is 56.11%, 75.27%, and 84.24% when compared to standard concrete at 28, 56, and 90, respectively. When GF is substituted with fine aggregate, the highest percentage reduction in strength loss is 48.62%, 46.24%, and 62.10% when compared to standard concrete at 28, 56, and 90, respectively.

Table 11: Acid Resistance test- HCL.

Mix ID	WEIGHT LOSS IN PERCENT			STRENGTH LOSS IN PERCENT		
	28 days	56 days	90 days	28 days	56 days	90 days
CM	3.62	5.21	5.8	10.21	11.48	14.96
5 %AF	3.45	4.97	5.37	9.24	10.11	14.30
10% AF	2.48	4.56	5.01	8.66	9.67	13.04
15 % AF	2.29	4.02	4.56	8.02	8.69	11.09
20% AF	1.74	3.23	3.56	6.54	7.23	9.12
25 % AF	1.86	3.42	3.79	6.98	7.53	9.65
5% NC	2.01	3.85	3.86	7.21	7.72	9.92
10% NC	2.85	3.94	3.92	7.46	8.08	10.5
15% NC	2.04	3.01	3.22	6.40	6.55	8.12
20% NC	3.10	4.14	3.99	7.99	8.83	12.33
25% NC	3.23	4.39	4.52	8.21	9.12	12.56
10% GP	2.30	4.51	4.98	8.59	9.44	12.89
20% GP	1.68	3.14	3.42	6.32	7.01	8.67
30% GP	2.55	3.66	3.88	6.87	7.85	9.23
40% GP	2.89	3.91	3.99	7.45	8.23	9.97
50% GP	3.12	4.36	4.56	7.81	8.69	10.65

Source: Authors, (2026).

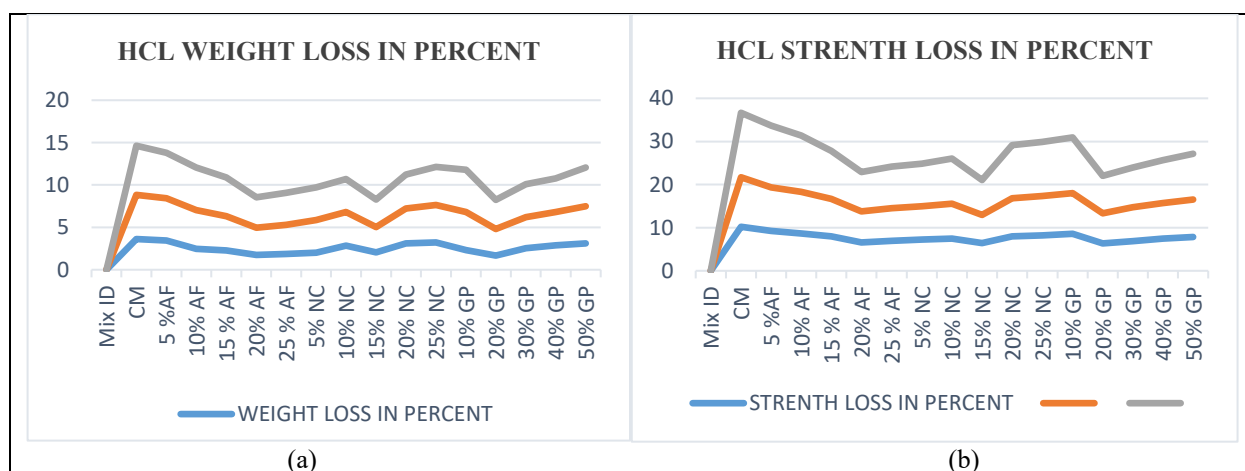


Figure 8: (a) Weight loss in percent in HCL (b) Strength loss in percent in HCL.

Source: Authors, (2026).

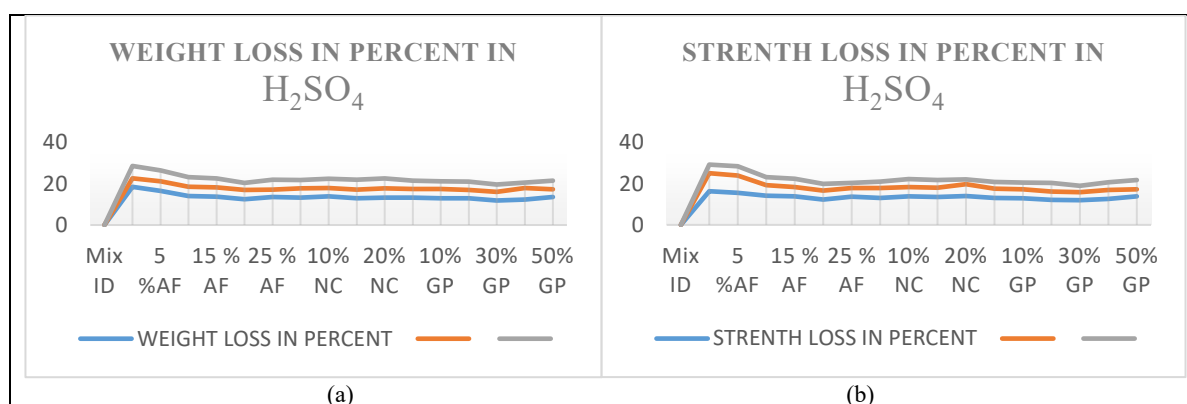
IV.8 ACID RESISTANCE TEST H2SO4:

When compared to normal concrete for 28, 56, and 90 days, the maximum percentage reduction in weight loss, when AF is replaced with cement, is AF 20 reduction in weight loss absorption is 48.08%, 33.69%, and 39.86 % when compared to normal concrete for 28, 56, and 90 days, respectively. when NC is replaced with cement, NC 15 is the maximum percentage reduction in strength loss is 41.95%, 31.67%, and 30.66% for 28, 56 and 90 days respectively. when GF30 is replaced with fine aggregate, GF 30 is the maximum percentage reduction in weight loss is 55.04%, 40.68%, and 45.56% when compared to normal concrete for 28, 56, and 90 days, respectively. When compared to normal concrete for 28, 56, and 90 days, the maximum percentage reduction in strength loss, when AF is replaced with cement, is AF 20 reduction in strength loss absorption is 48.08%, 33.69%, and 39.86 % when compared to normal concrete for 28, 56, and 90 days, respectively. when NC is replaced with cement, NC 15 is the maximum percentage reduction in strength loss is 41.95%, 31.67%, and 30.66% for 28, 56 and 90 days respectively. when GF30 is replaced with fine aggregate, GF 30 is the maximum percentage reduction in strength loss is 55.04%, 40.68%, and 45.56% when compared to normal concrete for 28, 56, and 90 days, respectively.

Table 12: Acid Resistance test H₂SO₄.

Mix ID	WEIGHT LOSS IN PERCENT			STRENGTH LOSS IN PERCENT		
	28 days	56 days	90 days	28 days	56 days	90 days
CM	18.48	22.62	28.6	16.32	25.08	29.25
5 %AF	16.45	21.2	26.45	15.5	23.96	28.49
10% AF	14.09	18.56	23.25	14.21	19.26	23.16
15 % AF	13.76	18.23	22.64	13.85	18.41	22.45
20% AF	12.48	16.92	20.45	12.33	16.65	19.96
25 % AF	13.55	17.13	21.91	13.61	17.92	20.31
5% NC	13.23	17.81	21.86	13.06	17.92	21.06
10% NC	13.88	17.99	22.42	13.86	18.32	22.25
15% NC	13.02	17.18	21.89	13.55	18.01	21.7
20% NC	13.32	17.69	22.62	14.05	19.74	22.03
25% NC	13.19	17.52	21.48	12.99	17.51	20.88
10% GP	13.01	17.38	21.23	12.84	17.26	20.59
20% GP	12.88	17.01	20.96	12.12	16.23	20.33
30% GP	11.92	16.08	19.65	11.92	15.86	19.03
40% GP	12.33	17.89	20.48	12.66	16.98	20.66
50% GP	13.57	17.25	21.56	13.87	17.26	21.74

Source: Authors, (2026).

Figure 9: (a) Weight loss in percent in H₂SO₄ (b) Strength loss in percent in H₂SO₄.

Source: Authors, (2026).

IV.9 SULPHATE ATTACK TEST:

When AF20 is substituted with cement, the largest percentage reduction in weight loss is 95.92%, 41.02%, and 38.15%, when compared to standard concrete for 28, 56, and 90, respectively. When NC15 is substituted with cement the greatest percentage reduction in weight loss absorption is 57.38%, 58.28%, and 39.37% compared to standard concrete for 28, 56, and 90, respectively. When GF30 is substituted with cement the greatest percentage reduction in weight loss absorption is 41.44%, 39.04%, and 40.13% compared to standard concrete for 28, 56, and 90, respectively. The largest percentage reduction in strength loss when AF20 is substituted with cement is 22.35%, 24.33%, and 27.04% when compared to standard concrete for 28, 56, and 90, respectively. When NC15 is substituted with cement, the highest percentage reduction in strength loss is 23.53%, 47.52%, 31.85% when compared to standard concrete for 28, 56, and 90, respectively. When GP30 is substituted with fine aggregate, the highest percentage reduction in strength loss is 53.66%, 65.25%, 52.42% when compared to standard concrete for 28, 56, and 90, respectively.

Table 13: Sulphate Attack test.

Mix ID	WEIGHT LOSS IN PERCENT			STRENGTH LOSS IN PERCENT		
	28 days	56 days	90 days	28 days	56 days	90 days
CM	1.92	2.58	3.04	7.56	8.94	11.02
5 %AF	1.66	2.26	2.54	6.96	7.99	9.96
10% AF	1.25	1.69	2	6.45	6.8	9.31
15 % AF	1.18	1.58	1.88	5.87	6.37	8.61
20% AF	0.98	1.12	1.65	5.07	5.83	8.04
25 % AF	1.08	1.38	1.77	5.61	6.01	8.23
5% NC	1.12	1.48	1.80	5.76	6.12	8.42
10% NC	1.24	1.67	1.98	6.42	6.78	9.17
15% NC	1.22	1.63	1.27	6.12	6.06	8.36
20% NC	1.49	1.80	1.89	6.89	6.88	8.99
25% NC	1.17	1.56	1.85	5.84	6.26	9.55
10% GP	1.14	1.52	1.82	5.79	6.18	8.46
20% GP	1.20	1	1.70	5	6.14	8.69
30% GP	0.92	1.30	1.48	4.92	5.41	7.23
40% GP	1.12	1.55	1.99	5.23	6.12	7.85
50% GP	1.56	2.33	2.54	6.01	6.89	8.21

Source: Authors, (2026).

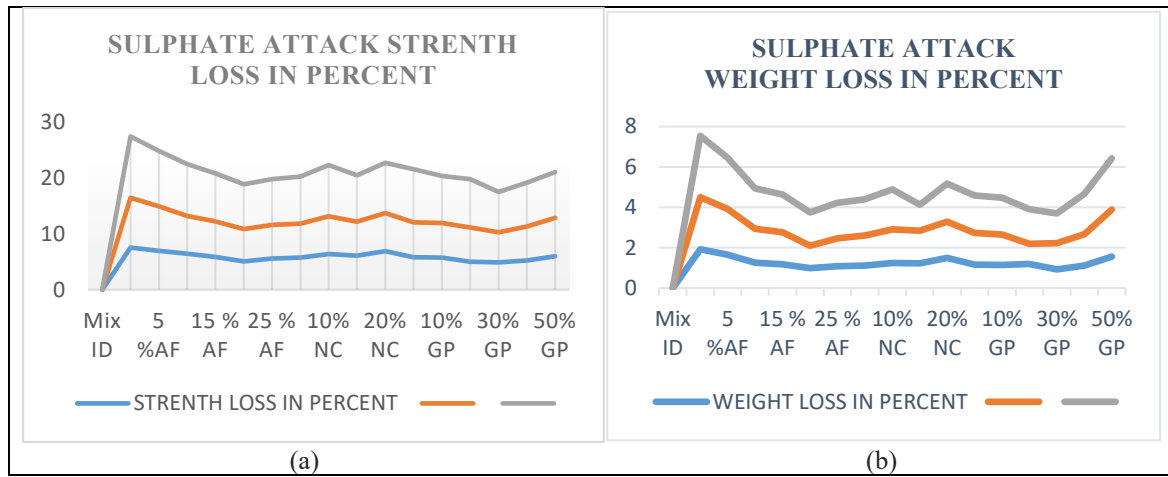


Figure 10: (a) Strength loss in percent in percent (b) Weight loss in percent in percent.
Source: Authors, (2026).

IV.10 MARINE RESISTANCE TEST:

When compared to conventional concrete for 28, 56, and 90, the largest percentage reduction in weight loss that occurs when AF is substituted with cement is 79.48%, 70.98%, and 71.81%, respectively. When GF is substituted with fine aggregate, the weight loss absorption can be reduced by a maximum percentage of 72.82%, 76.33%, and 54.69% when compared to conventional concrete for 28, 56, and 90, respectively. When compared to regular concrete for 28, 56, and 90, the largest percentage reduction in strength loss that occurs when AF is substituted with cement is 31.84%, 41.31%, and 37.56%, respectively. When compared to regular concrete for 28, 56, and 90, the largest percentage reduction in strength loss that occurs when GP is substituted with fine aggregate is 25.51%, 25.52%, and 34.33%, respectively. In previous studies when Alccofine and glass powder compared to normal conventional concrete in weight loss 83.58%,85.71%,75.16% and the strength loss is 38.55%,43.30%,45.58% is the best.

Table 14: Marine Environmental test.

Mix ID	WEIGHT LOSS IN PERCENT			STRENGTH LOSS IN PERCENT		
	28 days	56 days	90 days	28 days	56 days	90 days
CM	1.95	2.24	2.98	5.84	7.02	9.96
5 %AF	1.45	1.75	1.99	5.02	6.84	7.76
10% AF	1.06	1.50	1.82	4.88	6.32	7.26
15 % AF	0.59	1.14	1.87	4.62	5.69	6.92
20% AF	0.41	0.65	0.64	3.98	4.12	6.18
25 % AF	0.57	0.76	1.01	4.24	4.73	6.42
5% NC	0.55	0.83	1.32	4.33	5.17	6.51
10% NC	1.04	1.48	1.81	4.86	6.30	7.22
15% NC	0.46	1.13	1.67	4.79	5.14	6.11
20% NC	0.66	1.21	1.92	4.99	5.88	6.99
25% NC	0.58	1.10	2.43	5.58	5.95	7.88
10% GP	0.53	0.85	1.35	4.35	5.20	6.54
20% GP	0.44	0.62	0.98	4.06	4.66	6.12
30% GP	0.32	0.51	0.74	3.60	3.98	5.42
40% GP	1.23	1.87	0.98	3.97	4.56	5.87
50% GP	1.55	2.33	1.28	4.55	5.01	6.29

Source: Authors, (2026).

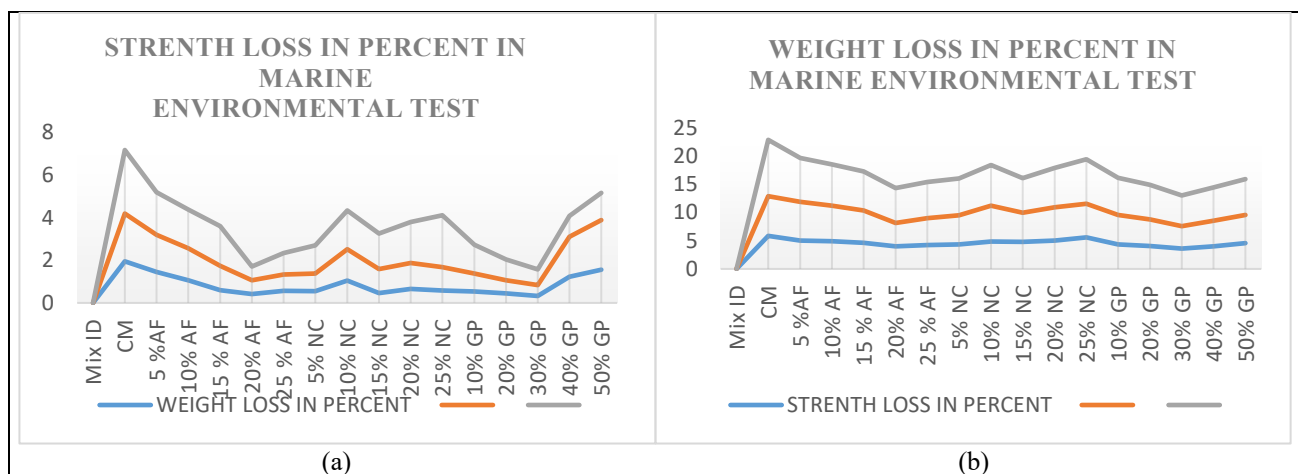


Figure 11: (a) Strength loss in percent (b) Weight loss in percent.
Source: Authors, (2026).

V. CONCLUSIONS

In this experiment, concrete cubes, cylinders, and beams were cast for varied proportions and evaluated at 7,14,28, 56, and 90 days for mechanical and durability. The reduction in water absorption in saturated stages when cement is substituted with 20% Alccofine and 15% nano clay when tested at 28, 58, and 90 days, respectively, compared to regular conventional concrete. When Glass Powder is utilized to replace 30% of the fine aggregate, water absorption is reduced by 3.4, 3.32, and 3.26. Sorptivity decrease when cement is substituted with 20% Alccofine 15% nano clay when tested at 60, 90, and 120 minutes with standard conventional concrete. Using GP as a 30% replacement for cement reduces water absorption by 0.076, 0.072, and 0.068 compared to standard concrete. The penetration value is also reduced to 1840 in AF20, NC15 and GP30 when compared normal conventional concrete. When AF is replaced with cement, the greatest percentage reduction in weight loss is 1.74, 3.23, and 3.56 when compared to regular concrete for 28, 56, and 90. Substituting cement for NC results in significant weight reductions of 2.04, 3.01, and 3.22 compared to ordinary concrete for 28, 56, and 90, respectively. Substituting GF with fine aggregate results in a 42.55, 3.66, and 3.88 percent reduction in weight loss absorption compared to ordinary concrete (28, 56, and 90, respectively).

When AF is substituted with cement, the largest percentage reduction in weight loss is 79.48%, 70.98%, and 71.81%, when compared to standard concrete for 28, 56, and 90, respectively. When GP is substituted with fine aggregate, the greatest percentage reduction in weight loss absorption is 72.82%, 76.33%, and 54.69% compared to standard concrete for 28, 56, and 90, respectively. When AF is substituted with cement, the highest percentage reduction in strength loss is 31.84%, 41.31%, and 37.56% compared to regular concrete for 28, 56, and 90, respectively. When GP is substituted with fine aggregate, the largest percentage reduction in strength loss is 25.51%, 25.52%, and 34.33% when compared to standard concrete at 28, 56, and 90 days respectively. In previous studies when Alccofine and glass powder compared to normal conventional concrete in weight loss 83.58%,85.71%,75.16% and the strength loss is 38.55%,43.30%,45.58% is the best. According to the aforementioned data, the best percentage replacement of cement by Alccofine is 20%, whereas the optimum percentage replacement of cement by Glass Powder is 50%. Furthermore, replacing cement with a mix of Alccofine and Glass Powder produces superior results when compared to standard conventional concrete.

VI. AUTHOR'S CONTRIBUTION

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Approval of the final text: K.E. Viswanathan, S. Naveen Kumar, S. Yuvaraj, C. Shankar.

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