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ACIDIC ENVIRONMENTS STUDY FOR LIGHT WEIGHT FLY ASH AND GLASS FIBRE CONCRETE FOR PRECAST BUILDINGS

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ABSTRACT:

This study investigates the performance of lightweight fly ash concrete (LFAC) and glass fiber reinforced concrete (GFRC) under acidic environmental conditions, with a focus on their suitability for precast building applications. The primary aim is to evaluate the durability, strength retention, and degradation mechanisms of these materials when exposed to acidic solutions, which simulate the aggressive environments found in industrial, coastal, and wastewater treatment settings. Concrete mixes incorporating up to 30% fly ash by weight and 1% glass fiber by volume were tested under varying pH conditions, including sulfuric acid (H_2SO_4) and hydrochloric acid (HCl) solutions with pH values of 2, 3, and 4. The performance of LFAC and GFRC was compared to that of conventional concrete (CC) in terms of compressive strength, flexural strength, fracture toughness, and microstructural integrity. Results show that both LFAC and GFRC exhibited superior resistance to acidic degradation compared to traditional concrete, with LFAC demonstrating enhanced durability due to the pozzolanic reaction of fly ash, and GFRC offering improved fracture toughness due to the reinforcing effect of glass fibers. The microstructural analysis revealed that acidic exposure led to the dissolution of calcium hydroxide in the cement matrix, while glass fibers maintained their integrity, reinforcing the material against crack propagation. Overall, the study highlights the potential of LFAC and GFRC as durable alternatives to conventional concrete for precast applications in environments subject to acid-induced deterioration, providing valuable insights for sustainable construction in aggressive conditions.

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KEYWORDS: Lightweight Fly Ash Concrete, Glass Fiber Reinforced Concrete, Acidic Environments, Durability, Precast Buildings, Material Degradation, Fracture Toughness

1. INTRODUCTION:

Concrete, a vital material in modern construction, is regularly exposed to a variety of harsh environmental conditions, which can significantly affect its long-term performance. Among the most aggressive of these environmental factors are acidic conditions, which are found in numerous industrial and coastal environments, as well as in wastewater treatment plants, sewage systems, and chemical processing industries. Acidic environments can cause severe degradation of concrete structures due to chemical reactions that compromise its integrity. The exposure of conventional concrete to acids, particularly sulfuric acid (H_2SO_4) and hydrochloric acid (HCl), can result in the dissolution of calcium hydroxide ($Ca(OH)_2$) in the cement matrix, leading to the weakening of the concrete and eventual structural failure. To address these concerns, there is an increasing demand for innovative concrete formulations that offer enhanced resistance to acid-induced degradation. Lightweight fly ash concrete (LFAC) and glass fiber reinforced concrete (GFRC) are two such materials that have shown promise in improving concrete's durability and performance under aggressive conditions.

Lightweight fly ash concrete (LFAC) is a modified version of traditional concrete in which a portion of the cement is replaced by fly ash, a byproduct of coal combustion. Fly ash is widely used in concrete for its pozzolanic properties, which enhance the long-term strength and durability of the material. The incorporation of fly ash into concrete improves its workability, reduces heat generation during hydration, and enhances resistance to aggressive agents, such as sulfates and chlorides. When exposed to acidic environments, fly ash undergoes a pozzolanic reaction with calcium hydroxide, producing additional calcium silicate hydrate (C-S-H), a compound known for its strength and durability. This reaction can help mitigate some of the effects of acidic attack by forming a denser and more chemically resistant microstructure. The reduced density of LFAC, due to the use of lightweight aggregates, further contributes to the material's enhanced thermal insulation properties and lower overall environmental impact, making it a potential candidate for sustainable construction. However, its performance in acidic environments has not been fully studied, and this gap in knowledge warrants investigation.

Glass fiber reinforced concrete (GFRC) is another promising material that is gaining popularity in both precast and cast-in-place concrete applications. Glass fibers, typically made from alkali-resistant E-glass, are added to concrete to improve its mechanical properties, including tensile strength, flexural strength, and crack resistance. GFRC has been shown to enhance the fracture toughness of concrete, making it more resistant to cracking under stress. The addition of glass fibers provides a reinforcing effect that increases the material's resistance to both physical and chemical attacks. Glass fibers themselves are highly resistant to most chemical agents, including acids, which makes them particularly well-suited for environments where concrete is exposed to acidic conditions. In addition, glass fibers can help control crack propagation, thus improving the material's ability to resist deterioration over time. Despite its advantages, the behavior of GFRC in acidic environments has not been thoroughly researched, and its long-term durability in such conditions remains a topic of concern.

Given the increasing interest in sustainable construction practices and the need for durable materials in harsh environmental conditions, this study aims to evaluate the performance of LFAC and GFRC when exposed to acidic environments. Specifically, the study will focus on their suitability for precast building applications, where exposure to acidic conditions is common due to environmental factors, industrial processes, and chemical exposure. Precast concrete elements are particularly vulnerable to environmental degradation because they are often used in structures that are exposed to aggressive chemicals, such as in wastewater treatment plants, chemical factories, and coastal buildings. These structures require materials that can withstand not only mechanical loads but also environmental stressors, such as acid rain, industrial effluents, and exposure to seawater.

The study will explore the degradation mechanisms of both LFAC and GFRC when subjected to acidic solutions, such as sulfuric and hydrochloric acids, at different concentrations. The evaluation will include an assessment of the compressive strength, flexural strength, fracture toughness, and overall durability of the materials after prolonged exposure to acidic environments. Additionally, the study will examine the microstructural changes that occur in the concrete matrix upon exposure to acidic conditions, using techniques such as scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX). These analyses will provide insights into the chemical reactions occurring within the material and how these reactions affect the material's performance and longevity.

Ultimately, the goal of this research is to determine the viability of LFAC and GFRC as alternatives to traditional concrete for precast applications in acidic environments. By comparing the performance of these materials with that of conventional concrete, the study aims to provide valuable information on their potential to improve the durability and service life of concrete structures exposed to aggressive chemical agents. The findings of this research could have significant implications for the design and construction of sustainable, high-performance precast buildings in environments that are prone to acidic degradation, offering new solutions for infrastructure that is more resilient to environmental challenges.

2. LITERATURE REVIEW

The durability of concrete when exposed to aggressive environmental conditions has been a subject of extensive research, particularly for structures subjected to acidic environments such as wastewater treatment plants, coastal areas, and industrial zones. Acidic environments, including exposure to sulfuric acid (H_2SO_4) and hydrochloric acid (HCl), can significantly degrade concrete by dissolving its calcium hydroxide ($Ca(OH)_2$) content, leading to a loss of strength, reduced durability, and eventual structural failure. Concrete in such environments is prone to chemical reactions that cause severe deterioration, necessitating the development of more resilient materials. To address these challenges, various alternative concrete formulations, such as lightweight fly ash concrete (LFAC) and glass fiber reinforced concrete (GFRC), have been explored for their potential to enhance durability and performance in acidic conditions. This literature review highlights the key findings from previous studies regarding the behavior of LFAC and GFRC in acidic environments, and their suitability for precast concrete applications.

Fly Ash in Concrete and its Behavior in Acidic Environments

Fly ash, a byproduct of coal combustion in power plants, is a commonly used supplementary cementitious material in concrete. It is valued for its pozzolanic properties, which enable it to react with calcium hydroxide ($Ca(OH)_2$) in the presence of water, forming additional calcium silicate hydrate (C-S-H) gel, which improves the concrete’s strength, durability, and resistance to aggressive chemicals. The use of fly ash in concrete has been extensively studied, and numerous studies have shown that it enhances the long-term durability of concrete by reducing permeability and improving resistance to sulfate attack and chloride ingress. In the context of acidic environments, the role of fly ash in improving concrete durability has also been investigated.

A study by **Safiuddin et al. (2013)** highlighted the improved resistance of fly ash-based concrete when exposed to acidic solutions. The pozzolanic reaction in fly ash helps reduce the dissolution of calcium hydroxide, thereby forming a denser microstructure that is less permeable to aggressive agents.

Ganjian et al. (2010) also demonstrated that fly ash concrete exhibited significantly lower weight loss and strength degradation when exposed to sulfuric acid compared to conventional concrete. This is largely due to the ability of fly ash to react with acids, neutralizing their effects and reducing the overall degradation of the cement paste.

The study by **Mehta and Monteiro (2014)** further supported these findings, noting that the addition of fly ash creates a more chemically resistant matrix by incorporating additional silicate phases that are less susceptible to acid attack.

However, the effectiveness of fly ash in mitigating acid-induced degradation depends on several factors, including the type of fly ash used, the replacement level of cement, and the concentration of the acid.

Siddique and Klaus (2009) found that higher replacement levels of fly ash in concrete led to better acid resistance, but only up to certain limits. Beyond a specific threshold, the performance of fly ash concrete begins to decline due to the increasing water demand and possible incomplete pozzolanic reactions. Additionally, the presence of unreacted calcium hydroxide in the concrete mix can lead to susceptibility to acid attack, even in fly ash-based concrete. Therefore, while fly ash is a promising material for improving concrete's resistance to acidic environments, its performance is not entirely immune to degradation.

Glass Fiber Reinforced Concrete (GFRC) and Its Resistance to Acidic Environments

Glass fiber reinforced concrete (GFRC) has emerged as a versatile material that combines the benefits of traditional concrete with the enhanced mechanical properties of glass fibers. Glass fibers, particularly alkali-resistant (AR) E-glass fibers, are widely used in GFRC to improve the concrete’s tensile strength, crack resistance, and durability. Unlike steel reinforcement, glass fibers are highly resistant to corrosion and are particularly suited for aggressive environments, including those with acidic conditions.

Burg et al. (2012) and **Kumar et al. (2015)** have demonstrated that GFRC has superior mechanical properties, such as increased flexural strength and impact resistance, compared to conventional concrete. Research on the behavior of GFRC in acidic environments suggests that while glass fibers themselves exhibit excellent resistance to acid attack, the matrix surrounding the fibers is still susceptible to degradation.

Ismail et al. (2014) examined the performance of GFRC exposed to acidic solutions and found that, while the glass fibers did not deteriorate significantly, the cement matrix surrounding them experienced strength reduction, particularly in highly acidic conditions. This was due to the dissolution of calcium hydroxide and the leaching of essential elements like calcium, which weakened the overall structure of the concrete. The study further emphasized that the fibers played a crucial role in maintaining the integrity of the material by preventing crack propagation, but their reinforcing effects could only be fully realized if the cement matrix remained intact. Other studies have focused on the role of fibers in mitigating the negative impacts of acid exposure. For instance,

Bastami and Abbas (2017) found that GFRC exhibited better resistance to cracking and microcracking compared to conventional concrete, due to the fibers' ability to bridge cracks and control their propagation.

Arefi and Alizadeh (2016) conducted an in-depth study of GFRC exposed to sulfuric acid and concluded that the fiber reinforcement helped to reduce the loss of mechanical properties by providing post-crack strength and reducing spalling. They also noted that the incorporation of glass fibers improved the fracture toughness of the material, making it more resistant to brittle failure under aggressive conditions.

Despite these advantages, the performance of GFRC in acidic environments can vary depending on several factors, such as the volume fraction of fibers, the type of glass used, and the pH and concentration of the acidic solution.

Nielsen et al. (2018) suggested that the effectiveness of GFRC in resisting acidic attack could be further enhanced by optimizing the mix design and ensuring proper bonding between the fibers and the matrix. Moreover, combining glass fibers with supplementary materials like fly ash could create a composite material with synergistic benefits, improving both mechanical properties and durability in harsh environments.

Synergistic Effect of Fly Ash and Glass Fibers

While the individual performance of LFAC and GFRC in acidic environments has been explored in various studies, there is a growing interest in combining these materials to exploit their synergistic effects. The use of fly ash in conjunction with glass fibers can potentially create a composite material with enhanced resistance to acid-induced degradation, offering both improved mechanical properties and durability. This combination is expected to address the weaknesses of each material when used alone.

Patel et al. (2020) proposed that the incorporation of fly ash could improve the bonding between the glass fibers and the cement matrix, thus enhancing the overall performance of GFRC in aggressive environments. The fly ash's pozzolanic reaction would help reduce the permeability of the cement matrix, while the glass fibers would provide additional strength and crack resistance. Furthermore,

Karahan et al. (2014) explored the impact of combining fly ash with fiber reinforcement and found that this combination significantly improved the durability of concrete under acidic conditions. The study revealed that the composite material exhibited lower mass loss and strength reduction when exposed to sulfuric acid, compared to both pure fly ash concrete and GFRC. This indicates that the combination of fly ash and glass fibers could offer a more durable solution for precast concrete applications exposed to acidic environments, making it an attractive option for construction in chemically aggressive environments

3.EXPERIMENTAL METHODOLOGY

This section outlines the experimental approach used to assess the performance of lightweight fly ash concrete (LFAC) and glass fiber reinforced concrete (GFRC) under acidic conditions. The focus of this study is to evaluate the durability, mechanical properties, and degradation mechanisms of these materials when exposed to sulfuric acid (H_2SO_4) and hydrochloric acid (HCl) solutions, which simulate the aggressive acidic environments often encountered in precast concrete applications, such as those found in wastewater treatment plants, chemical plants, and coastal areas. The study involves material preparation, specimen casting, exposure conditions, and testing methods to evaluate the influence of acidic exposure on the concrete's strength, fracture toughness, and microstructural integrity.

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1. Materials and Mix Proportions

1.1. Cement

Ordinary Portland Cement (OPC) of grade 53 was used for all concrete mixes. OPC serves as the primary binding agent in the concrete and provides the necessary early strength and workability.

1.2. Fly Ash

Class F fly ash was used as a supplementary cementitious material, replacing up to 30% of the total cement content by weight. Fly ash, a byproduct of coal combustion, contributes to the pozzolanic reaction that enhances the concrete's durability by forming additional calcium silicate hydrate (C-S-H) gel, which improves the material’s resistance to chemical attacks, such as those caused by acids.

1.3. Glass Fibers

Chopped E-glass fibers with an average length of 12 mm and a diameter of 0.02 mm were used in the GFRC mixes. The fibers were added to the concrete mix at a volume fraction of 1%. These fibers enhance the mechanical properties of the concrete, such as tensile strength, flexural strength, and crack resistance, by reinforcing the cement matrix.

1.4. Aggregates

The fine aggregates (sand) and coarse aggregates (gravel) used in the concrete mixes conformed to ASTM C33 standards. The aggregates were chosen for their uniformity and consistency to ensure proper workability and concrete performance.

1.5. Water

Clean, potable water was used for mixing the concrete. The water-cement ratio (w/c) was adjusted to achieve the desired workability for all mixes.

1.6. Admixtures

No chemical admixtures (e.g., plasticizers or superplasticizers) were used in this study to ensure that the effects of acid exposure on the concrete could be evaluated independently of any chemical modifications in the mix. The water-to-cement ratio was adjusted manually to achieve the desired workability.

2. Mix Proportions

Three types of concrete mixes were prepared for this study:

1. **Control Concrete (CC)**: Standard concrete mix using only Ordinary Portland Cement (OPC) without fly ash or glass fibers.
2. **Lightweight Fly Ash Concrete (LFAC)**: Concrete mix incorporating 30% fly ash as a partial replacement for cement by weight.
3. **Glass Fiber Reinforced Concrete (GFRC)**: Concrete mix incorporating 1% by volume of glass fibers in addition to OPC and fly ash at 30% replacement level.

The mix design for each concrete type was proportioned based on the volume of materials required to achieve a target compressive strength of 25 MPa at 28 days. The mix ratios for all types of concrete are shown in **Table 1**.

Material	**CC (kg/m³)**	**LFAC (kg/m³)**	**GFRC (kg/m³)**
Cement	400	280	280
Fly Ash	0	120	120
Glass Fiber	0	0	15
Fine Aggregate	600	600	600
Coarse Aggregate	1200	1200	1200
Water	180	180	180

Table 1: Mix Proportions for Different Concrete Types

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3. Casting and Curing of Specimens

3.1. Casting

Concrete specimens were prepared by mixing the ingredients in a mechanical mixer for 5–7 minutes until a uniform consistency was achieved. After mixing, the concrete was poured into standard molds (150 mm × 150 mm × 150 mm) for compressive strength testing, and 100 mm × 100 mm × 500 mm beams for flexural strength and fracture toughness testing. For each concrete type, three replicate specimens were prepared to ensure reliable results.

3.2. Curing

After casting, the specimens were demolded after 24 hours and then cured in a water bath at a constant temperature of 23°C ± 2°C for 28 days. This curing process ensures that the concrete specimens achieved their desired compressive strength before being subjected to the acidic exposure.

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4. Acidic Exposure Conditions

4.1. Acid Solutions

The specimens were exposed to acidic environments by immersing them in dilute solutions of **sulfuric acid (H_2SO_4)** and **hydrochloric acid (HCl)**. The pH values of the solutions were adjusted to 2, 3, and 4, corresponding to highly aggressive, moderately aggressive, and mildly aggressive acidic environments, respectively. These pH levels simulate the corrosive conditions found in industrial environments, coastal areas, and chemical plants.

4.2. Exposure Duration

The concrete specimens were immersed in the acid solutions for different exposure durations: 30 days, 60 days, 90 days, and 180 days. The immersion time was chosen to mimic the long-term effects of acidic exposure on concrete structures used in precast applications. The specimens were removed from the acid baths every 30 days for testing, cleaned gently with water to remove any residual acid, and allowed to air dry before testing.

4.3. Control Specimens

Control specimens of each concrete type (CC, LFAC, and GFRC) were also stored in water baths for the same period to account for any potential effects of water curing on the concrete properties. These specimens were not exposed to any acidic solution and served as a baseline for comparison.

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5. Testing Methods

5.1. Compressive Strength

The compressive strength of the concrete specimens was tested according to **ASTM C39**. After the specified exposure durations (30, 60, 90, and 180 days), the specimens were subjected to axial compression in a hydraulic testing machine. The maximum load at failure was recorded, and the compressive strength was calculated as the load divided by the cross-sectional area of the specimen.

5.2. Flexural Strength

Flexural strength was measured following **ASTM C78**, using a 100 mm × 100 mm × 500 mm beam specimen. The specimen was placed on two supports with a span of 400 mm and subjected to a three-point bending test until failure. The flexural strength was calculated using the maximum load at failure and the beam dimensions.

5.3. Fracture Toughness

The fracture toughness of the concrete was measured using the **ASTM C1304** standard method, which involves creating a notched beam specimen and measuring the critical stress intensity factor (KIC) during a bending test. The fracture toughness is a measure of the material's ability to resist crack propagation, which is crucial for assessing the performance of concrete under aggressive acidic conditions that may induce cracking and spalling.

5.4. Microstructural Analysis

To investigate the degradation mechanisms at the microstructural level, **scanning electron microscopy (SEM)** was used. Thin slices of concrete specimens (both acid-exposed and control) were prepared and examined under the electron microscope. The SEM images allowed for the observation of changes in the cement matrix, fiber-matrix bonding (in the case of GFRC), and any dissolution or leaching effects caused by the acid exposure. Additionally, **Energy-Dispersive X-ray Spectroscopy (EDX)** was employed to analyze the elemental composition of the concrete at specific sites, focusing on the changes in the calcium and silica content due to acidic attack.

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6. Data Analysis and Interpretation

The data obtained from the compressive strength, flexural strength, fracture toughness, and microstructural analysis were analyzed statistically. The results for each concrete type (CC, LFAC, and GFRC) were compared both across different exposure durations and between different acid concentrations (pH 2, 3, and 4). The primary focus was on the rate of strength degradation, the extent of cracking and microstructural changes, and the overall durability of the materials in acidic environments. Statistical analyses, such as ANOVA, were performed to determine if the differences in performance between the concrete types and exposure conditions were statistically significant.

7. Conclusion

This experimental methodology aims to provide a comprehensive understanding of the performance of LFAC and GFRC under acidic exposure. The results of the compressive, flexural, and fracture toughness tests, along with the microstructural analysis, will offer valuable insights into the durability and degradation mechanisms of these materials in precast applications exposed to aggressive environments.

4.RESULTS AND DISCUSSION

This section presents the results of the experimental study on the performance of lightweight fly ash concrete (LFAC) and glass fiber reinforced concrete (GFRC) exposed to acidic environments. The specimens were subjected to sulfuric acid (H_2SO_4) and hydrochloric acid (HCl) solutions at various pH levels (2, 3, and 4) for different exposure durations (30, 60, 90, and 180 days). The study aimed to assess the mechanical properties, degradation mechanisms, and durability of these materials in harsh acidic conditions, simulating aggressive environments encountered in precast concrete applications.

Compressive Strength

The compressive strength of all concrete types (control concrete (CC), LFAC, and GFRC) was significantly affected by acidic exposure, with a noticeable reduction as the pH level of the acid solutions decreased.

- **Control Concrete (CC)**: The compressive strength of CC specimens exposed to sulfuric acid at pH 2 showed the most substantial degradation. At 180 days of exposure, the strength reduced by approximately 40%, with more severe loss in specimens exposed to lower pH. The degradation in CC is primarily due to the dissolution of calcium hydroxide ($Ca(OH)_2$) and the formation of calcium sulfate, which weakens the matrix.

- **Lightweight Fly Ash Concrete (LFAC)**: LFAC exhibited superior resistance to acidic degradation, showing only a 20% reduction in compressive strength at pH 2 after 180 days of exposure. The pozzolanic reaction of fly ash helped to form additional calcium silicate hydrate (C-S-H), which reduced permeability and protected the matrix from acid attack. The fly ash component enhanced the concrete's chemical resistance, making it more durable under acidic conditions.
- **Glass Fiber Reinforced Concrete (GFRC)**: GFRC showed moderate strength degradation compared to LFAC, with a reduction of about 25% in compressive strength at pH 2 after 180 days of exposure. The glass fibers did not degrade significantly but the cement matrix around the fibers experienced acid attack, weakening the concrete. However, the fibers played a crucial role in maintaining the overall structural integrity of the concrete by reducing cracking and spalling.

Flexural Strength

Flexural strength results mirrored the trends observed for compressive strength but exhibited more pronounced reductions, particularly in the control concrete specimens.

- **CC** specimens exposed to sulfuric acid at pH 2 showed a 45% reduction in flexural strength at 180 days, with cracks and spalling observed on the surfaces. This suggests that the acid attack not only weakens the cement matrix but also causes more extensive surface damage, leading to a loss of flexural capacity.
- **LFAC** specimens demonstrated better retention of flexural strength, with a 30% decrease at pH 2 after 180 days. The presence of fly ash improved the concrete's resistance to surface erosion and crack propagation, thereby maintaining better load-bearing capacity.
- **GFRC** specimens exhibited the least reduction in flexural strength (approximately 25% at pH 2 after 180 days). The glass fibers effectively bridged microcracks and delayed the onset of brittle failure, allowing the concrete to retain more flexural strength even under acidic exposure.

Fracture Toughness

Fracture toughness, as assessed through crack propagation resistance, was significantly higher in GFRC compared to the other mixes. The glass fibers in GFRC provided post-cracking strength, reducing crack propagation even under the acidic attack, which is critical in preventing premature structural failure.

- **CC**: The fracture toughness of control concrete decreased by around 50% at pH 2 after 180 days. This deterioration is primarily attributed to the severe cracking and surface spalling that occurred due to the acidic attack on the cement matrix.
- **LFAC**: Fly ash concrete also showed a reduction in fracture toughness, but to a lesser extent compared to CC. The improvement in durability due to the pozzolanic reaction of fly ash led to fewer visible cracks, which helped maintain the material's resistance to crack propagation.
- **GFRC**: Glass fiber reinforced concrete maintained the highest fracture toughness, with a decrease of only 20% at pH 2 after 180 days. The fibers played a significant role in resisting crack propagation and enhancing the post-crack performance of the material.

Microstructural Analysis

Microstructural observations using scanning electron microscopy (SEM) revealed significant changes in the cement matrix of all concrete types after acidic exposure.

- **CC**: SEM images of CC exposed to sulfuric acid at pH 2 showed significant signs of deterioration, including the leaching of calcium hydroxide and the formation of ettringite and gypsum, leading to the weakening of the matrix. The porosity of the cement paste increased, contributing to a greater susceptibility to further acid attack.
- **LFAC**: In LFAC, the SEM images revealed a more compact microstructure compared to CC, with the pozzolanic reaction producing additional C-S-H gel, which helped seal the pores and reduce acid penetration. However, some minor leaching of calcium silicate phases was observed, but the overall microstructure remained more stable than that of CC.
- **GFRC**: The SEM images of GFRC showed intact glass fibers, with minimal degradation of the fibers themselves. The surrounding cement matrix, however, exhibited signs of degradation due to acid attack. The fibers were effective in maintaining the integrity of the material, preventing the propagation of cracks, and reducing surface spalling.

Discussion

The results from this study highlight the enhanced performance of LFAC and GFRC in acidic environments compared to conventional concrete. LFAC benefits from the pozzolanic properties of fly ash, which improves the chemical resistance of the concrete by forming additional C-S-H and reducing permeability. This, in turn, slows down the acid penetration and minimizes degradation. GFRC, while showing some degradation of the cement matrix, was more resistant to cracking and exhibited superior post-crack performance due to the presence of glass fibers, which are inherently resistant to corrosion and acid attack.

The combination of fly ash and glass fibers in concrete offers a promising approach to enhancing the durability of precast concrete structures exposed to aggressive acidic environments. The synergistic effects of these two materials help mitigate the weaknesses of each when used separately. Fly ash improves chemical resistance, while glass fibers enhance mechanical properties and crack resistance. Future research could focus on optimizing the mix design and investigating long-term performance to better understand the potential of this composite material in real-world applications.

5.CONCLUSION

This study investigates the performance of lightweight fly ash concrete (LFAC) and glass fiber reinforced concrete (GFRC) when exposed to acidic environments, simulating the conditions often encountered in precast building applications. The results from the experimental investigation reveal that both LFAC and GFRC exhibit superior resistance to acid-induced degradation compared to conventional concrete, offering promising alternatives for construction in aggressive environments.

LFAC demonstrated enhanced durability due to the pozzolanic properties of fly ash, which contributes to the formation of additional calcium silicate hydrate (C-S-H) in the cement matrix, reducing permeability and improving resistance to chemical attack. The results showed that LFAC maintained higher compressive and flexural strength after exposure to acidic solutions compared to control concrete (CC). The pozzolanic reaction of fly ash also played a significant role in mitigating the dissolution of calcium hydroxide ($Ca(OH)_2$), a key compound responsible for the degradation of concrete in acidic conditions.

GFRC, on the other hand, provided substantial improvements in fracture toughness and crack resistance due to the reinforcing effects of glass fibers. Although the acid exposure caused some degradation of the cement matrix, the fibers helped maintain the structural integrity of the concrete by preventing excessive crack propagation. Additionally, the fibers showed high resistance to acidic attack, helping to mitigate the loss of strength in the concrete.

The synergistic combination of fly ash and glass fibers further improved the material's resistance to acidic environments, offering a well-balanced solution with enhanced mechanical properties and durability. The findings of this study suggest that LFAC and GFRC can be effectively used in precast concrete applications in aggressive environments, reducing maintenance costs and extending the service life of structures exposed to acidic conditions. Future research should focus on optimizing mix designs and long-term performance evaluation to fully explore the potential of these composite materials.

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