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Physico-Mechanical Properties of High-Strength Concrete Containing Supplementary Cementitious Materials Subjected to Acid Attack

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ABSTRACT

This study investigates the resistance of high-strength concrete (HSC) to sulfuric acid exposure, focusing on its application in constructing floors in acid storage plants, sewage manholes, and other areas exposed to acid. The aggressive chemical attack from acids poses a significant threat to concrete durability and strength. The study also examines the effect of supplementary cementitious materials (SCMs) on enhancing the resistance of HSC to acid attack. Six HSC mixtures were evaluated: two control mixes, two mixes contained 25% cement replacement, one using fly ash Type-F and others using slag. Three mixes have been cured in water for 3 days, while others have been cured in water for 28 days. All mixtures were immersed in a 3% sulfuric acid solution for a period of 28 or 56 days. To assess concrete deterioration, compressive strength, tensile strength, and weight loss were measured. The study demonstrated that exposure to sulfuric acid caused significant surface erosion on HSC. All HSC mixtures experienced strength loss, especially the control mix. The presence of slag enhanced the acid resistance of HSC, particularly for the 3-day cured specimens. While the presence of fly ash enhanced the acid resistance of HSC for the 28-day cured specimens.

Keywords:

Acid attack; High strength concrete; Supplementary cementitious materials; Durability; Concrete deterioration.

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1. INTRODUCTION

Acids generally damage concrete by reacting with calcium hydroxide present in hydrated portland cement [1]. The primary reason behind acid attacks is the expansion of acid sources from the growth of industrial areas, which leads to the contact of acid media with concrete structures. The acid attack can be caused by acid rain, acidic wastewater, natural acidic water, and silage effluents. In addition, the alkaline nature makes concrete highly vulnerable to acidic attack [2]. Concrete is severely damaged by the action of hydrochloric, nitric, sulfuric, chloric, and chromic acids, which cause the decomposition of all cement hydration products [1]. Sulfuric acid can be present in various environments surrounding concrete structures. The areas where sulfuric acid can exist and damage concrete are groundwater, industrial wastewater, underground sewage systems, and acid rain. Also, some bacteria turn sewage into sulfuric acid [3]. Sulfuric acid harms concrete as the acid creates calcium sulfate, which damages the concrete through sulfate attack. The rate of deterioration of concrete structures depends on the concentration of sulfuric acid and the amount of acid solution that can reach the concrete surface [4]. The pronounced effect of sulfuric acid on the floor of one of the acid storage warehouses is clear in the depicted image in Fig. 1.

Fig.1 Sulfuric acid impact on warehouse floor in Mosul industrial area.

Many researchers have studied the effects of acid attacks on concrete, aiming to improve its resistance and performance. Among them, Goyal et al. [2] investigated the durability of concrete exposed to 1% concentration of sulfuric, hydrochloric, and nitric acids. The researchers analyzed concrete degradation over a year by measuring the mass and strength loss. Their results determined that ternary mixes containing silica fume and fly ash were more resistant to sulfuric, hydrochloric, and nitric acids than the binary mixes containing silica fume. SCMs, such as fly ash and silica fume effectively mitigated the detrimental effect of these acids on concrete. Joorabchian [4] exposed concrete mixtures containing metakaolin (MK) and limestone filler (LF) to sulfuric acid and found that the use of MK and LF improved concrete performance and enhanced its resistance to sulfuric acid attack. Fattuhi and Hughes [5] studied the effects of sulfuric acid on both concrete and cement paste. The conclusion was that weight loss increased with increasing an amount of cement causing deterioration of concrete under acid attack. Bakharev et al. [6] compared the performance of alkali-activated slag (AAS) concrete with ordinary Portland cement (OPC) concrete when exposed to acetic acid. Their results showed that AAS concrete exhibited better resistance to acid attack compared to OPC concrete with less weight and strength loss. Kawai et al. [7] studied the effect of exposure to sulfuric acid on the erosion depth of concrete. The study used normal strength concrete with mineral additives (fly ash and blast furnace slag). The study revealed that the incorporation of these mineral additives reduced the erosion depth of concrete when exposed to an acid solution. Barbhuiya and Kumala [8] investigated sustainable concrete performance under nitric and sulfuric acid attack. The study concluded that replacing a percentage of cement with fly ash and ultra-fine fly ash exhibited the least loss in mass and compressive strength. Anusiya and Oviya [9] compared the durability of reactive powder concrete (RPC) and high-strength concrete (HSC) under acid attack. RPC demonstrated superior compressive and flexural strength, as well as lower permeability, compared to HSC. Rao et al. [10] studied the acid resistance of Quaternary Blended Cement Concrete (QBCC) using recycled aggregate. They found that using QBCC with recycled aggregate resulted in less reduction in strength and weight. Torres et al. [11] investigated the impact of 0.5%, 1% and 3% concentrations of sulfuric acid on the mechanical properties of high-performance concrete (HPC). Their findings show that the strength of the HPC decreased with higher acid concentration and prolonged immersion time. Aygörmez and Canpolat [12] exposed Geopolymer composites made from metakaolin (MK), silica fume (SF), slag (S), and colemanite waste (C) to two types of acid hydrochloric and sulfuric acid. They observed that sulfuric acid had more damaging effects on geopolymer composites than hydrochloric acid. Ali and Ibrahim [13] investigated the effects of both nitric and sulfuric acid on the mechanical properties of reactive powder concrete (RPC). They found that nitric acid increased losses in compressive and flexural strengths compared to sulfuric acid, while sulfuric acid caused an increase in the weight loss of concrete. Dhundasi et al. [14] investigated the durability properties of RPC under sulfuric acid attack. The results showed that the strength and mass of the specimens significantly decreased with high concentrations of sulfuric acid, indicating the negative impact on RPC durability.

Normal strength concrete in sewage manholes is susceptible to erosion caused by acid attacks from wastewater [15]. Therefore, this study focuses on the using high-strength concrete (HSC) to enhance acid resistance in manhole construction. HSC is defined as having a compressive strength of 55 MPa or higher [16].

Mosul city is currently undergoing a sewage system upgrade. Officials are temporarily redirecting water as shown in Fig.2, excavating trenches, installing pipes, casting manholes, and redirecting water again after three days. This rapid exposure to water containing acids reaches the newly cast manholes within just three days of casting. Therefore, a study was conducted to investigate the impact of this rapid acid exposure on the concrete. The specimens in this study underwent exposure to acid after a curing period of 3 days in water, in addition to the standard curing of 28 days.

Fig.2 Temporarily redirecting water for a sewage project in Mosul City, Iraq.

2. EXPERIMENTAL PROGRAM

This section deals with the experimental procedures in this study, including materials and their properties, mix proportions, specimen preparation, casting, curing, exposure to sulfuric acid, and testing methods.

2.1. Materials

Materials used in the study include ordinary portland cement (OPC) Type I from "Mass Cement Factory," conforming to Iraqi specification IQS No.5/1984 [17], with a specific gravity of 3.15. Chemical composition analysis and physical properties are detailed in Tables 1 and 2, respectively.

Supplementary cementitious materials (SCMs) include Silica Fume (SF) from "ECA Company" (specific gravity: 2.25), conforming to ASTM C1240-20 [18]. Fly Ash (FA) type F from "Euro Build Company" (specific surface area: 360 m2/kg, specific gravity: 2.4) conforming to ASTM C-618-19 standards [19]. GGBS (Slag) from "Songhe Industrial Company" grade S95 (specific surface area: 418 m2/kg, specific gravity: 2.9), complies with the requirements of BS 6699 [20]. The Chemical properties of SCMs are provided in Table 1.

The fine aggregate consists of natural river sand from the "Nineveh Zone Kanhash area" with a specific gravity of 2.65 and 0.5% absorption. Grading is detailed in Table 3.

The coarse aggregate (CA) consists of natural rounded coarse aggregate with a maximum size of 12 mm, complying with Iraqi specification IQS No.45/1984 [21]. Physical properties and grading are presented in Tables 4 and 5, respectively.

Admixtures include the superplasticizer "Hyperplast PC200" with a specific gravity of 1.05 and Polypropylene Fiber (PP fiber) with a length of 9mm from "Sika Company".

Potable water from the network system was used for both mixing and curing the samples.

Table 1: Chemical composition of cement and SCMs (value %)

Chemical Composition	Cement	Silica Fume	Fly-Ash	*GGBS*
SiO_2	19.5	95	47.67	31.86
Al_2O_3	4.9	1.38	27.73	16.67
Fe_2O_3	3.29	0.02	15.42	0.86
CaO	64.25	0.018	5.11	38.72
MgO	3.04	0.01	2.65	8.41
SO_3	2.64	0.3	0.34	0.72
Free Lime	1.32	-	-	-
Loss on ignition	2.06	1.05	3.71	0.2
Insoluble residue	0.75	-	-	-

Table 2: Physical properties of cement

Physical Properties	Test Results	Limits of IQS No.5/1984
Standard Consistency (w/c)	0.27	----
Initial Setting Time (min.)	150	≥ 45 min
Final Setting Time (hrs.)	5	≤ 10 hrs.
Compressive strength at:		
3 days (MPa)	21.7	≥ 15
7 days (MPa)	32.5	≥ 23
Fineness on No. 170 sieve (%)	2.9	----

Table 3: Grading of fine aggregate.

Sieve size (mm)	Wt. retained (gm)	Cumulative wt. retained (gm)	Cumulative % retained (gm)
4.75	0	0	0
2.36	142	142	14.2
1.18	180	322	32.2
0.6	210	532	53.2
0.3	304	836	83.6
0.15	164	1000	100
Fineness modulus			2.8

Table 4: Physical properties of coarse aggregate

Properties	Results
Specific Gravity	2.67
Absorption (%)	0.5
Compact Bulk Density (kg/m³)	1770
Loose Bulk Density (kg/m³)	1623

Table 5: Grading of course aggregate.

Sieve size (mm)	Passing %	IQS Limits No.45/1984
20 (3/4in)	100	100
14 (1/2in)	96	90-100
10 (3/8in)	63	50-85
5 (3/16in)	0	0-10

2.2. Mix Proportions

All HSC mixtures used 600 kg/m^3 of Cementitious Materials (CMs) with 10% silica fume by weight. The mixtures were HSC-C (control), HSC-FA (25% fly ash of cement weight), and HSC-S (25% GGBS of cement weight). Each mix had 0.15% PP Fiber, 1.5% superplasticizer of CMs weight, and 0.25 a water-to-cementitious materials ratio *(w/cm)*. The details of the mixtures are presented in Table 6.

Table 6. Composition of HSC mixtures

HSC	HSC-C	HSC-FA	HSC-S
Cement Kg/m³	542	406	406
Sand Kg/m³	602	602	602
CA Kg/m³	1144	1144	1144
SF Kg/m³	60	60	60
FA Kg/m³	0	135	0
Slag Kg/m³	0	0	135
w/cm	0.25	0.25	0.25
PP Fiber %	0.15	0.15	0.15
Sp %	1.5	1.5	1.5

2.3. Mixing and Preparing Specimens

The mixing process, in accordance with ASTM C 192 [22], involved adding coarse aggregate, one-third of the mixing water, and initiating the mixer. Fine aggregate, cement, SCMs, remaining water, and PP fiber were gradually introduced during a 3-minute mixing period, followed by a 3-minute rest and a final 2-minute mix.

For workability assessment, a slump test per ASTM C 143 [23] was conducted. The mixture was placed in molds, compacted using a vibrating table, and cured at 22 ± 3°C. After 24 hours, specimens were demolded, split into two groups, and submerged in a water tank for either 3 or 28 days. Subsequently, specimens were exposed to sulfuric acid for 28 or 56 days.

2.4. Sulfuric Acid (H_2S0_4)

Sulfuric acid with a concentration of 3% and a pH of approximately 0.85 is utilized. The acid is replaced every two weeks or when a significant pH change is detected, and the basins are cleaned during replacement. The pH of the acid is continuously monitored directly using a pH meter.

The acid is stored in two polyethylene basins, with one designated for cube specimens and the other for cylinder specimens. These basins are shown in Fig. 3.

Fig.3 Sulfuric acid basins

2.5. Experimental Work Procedure

The steps involved in the practical aspects of this study, which were mentioned earlier, are clarified through the detailed process outlined in the flowchart presented in Fig. 4.

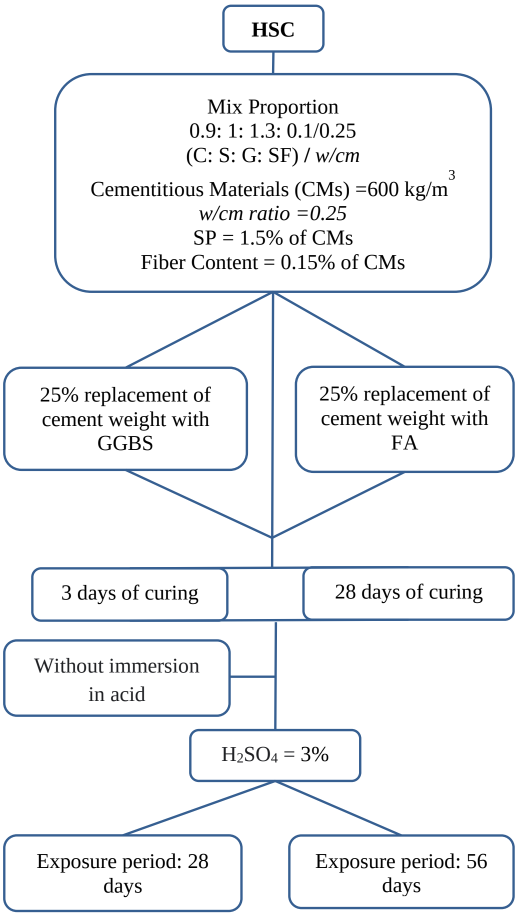

Fig.4 Experimental work flowchart

2.6. Testing Methods

Concrete specimens underwent acid resistance evaluation through visual observation, compressive strength, splitting tensile strength, and weight loss. For visual observation, specimens were monitored visually after being placed in sulfuric acid basins, and the changes that occurred were observed and recorded. For compressive strength, 54 cubic specimens (100 x 100 x 100 mm) were tested according to BS EN 12390-3:2019 [24], cured for 3 or 28 days, exposed to acid for 28 or 56 days. The percentage reduction in strength was calculated using Eq. (1).

$$\%\,Reduction\ in\ strength = \frac{fi - fs}{fi} * 100 \quad (1)$$

Where *fi* is the strength before acid exposure (MPa), and *fs* is the strength after acid exposure (MPa).

Splitting tensile strength was assessed using 54 cylindrical specimens (100 x 200 mm) per ASTM C496 [25], following a similar curing and exposure regimen, with the percentage reduction calculated using Eq. (1). Weight loss was measured by drying specimens at 105°C for 24 hours, immersing in sulfuric acid, cleaning, drying again, and calculating the percentage of weight loss using the initial and final weights with Eq. (2).

$$\%\, Weight\ loss = \frac{Wi - Ws}{Wi} * 100 \quad (2)$$

Where *wi* is the weight before acid exposure (gm), and *ws* is the weight after acid exposure (gm).

3. RESULTS AND DISCUSSION

This section discusses the performance of high-strength concrete (HSC) under acid attack, presenting results from visual observations, mechanical tests (compressive and splitting tensile strength), and weight loss measurements. The results are analyzed in detail and discussed at the end of this section.

3.1. Visual Effects of Sulfuric Acid on HSC Specimens

After the end of the curing period, the specimens were immersed in a sulfuric acid solution, and their visual changes were monitored. No changes were observed in the first few days of immersion. However, after 3 days, visible erosion effects began to appear on the surface of the specimens. The severity of the erosion increased with time, and after 28 days, surface layers began to peel off, exposing the gravel and polypropylene fibers (PP fibers) used in the high strength concrete (HSC) mixtures. By the 56th day, the outer layers of the specimens had separated significantly, and the surface became noticeably weaker as shown in Fig.5.

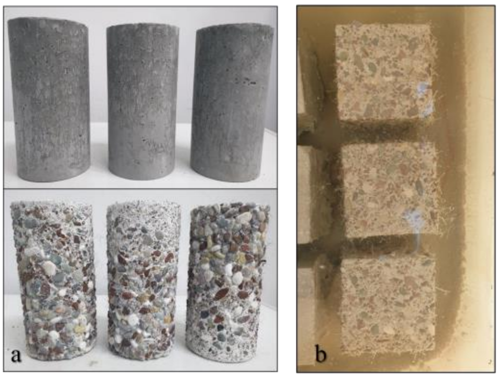

Fig.5 a: HSC-C cylinder specimens before and after exposure to sulfuric acid for 56 days.
b: HSC-C cubic specimens after immersion in sulfuric acid.

No significant visual differences were observed between specimens containing different supplementary cementitious materials. Similarly, there was no significant difference between specimens cured for 3 days and those cured for 28 days before exposure to acid. Therefore, to accurately assess the deterioration of concrete in different mixtures, additional testing, such as compressive and split tensile strength tests, is recommended.

3.2. Slump Test

The incorporation of SCMs increases the workability of freshly mixed high-strength concrete (HSC), as shown in Table 7.

Table 7: Slump results

High Strength Concrete	Slump (cm)
HSC-C	15.5
HSC-FA	17.75
HSC-S	18

3.3. Compressive Strength Loss

The compressive strength results for concrete specimens (HSC-C, HSC-FA, and HSC-S), cured for 3 days in water and exposed to an acid solution for 0, 28, and 56 days, is presented in Fig. 6. At 28 days, slight differences in strength loss were observed, with HSC-C, HSC-FA, and HSC-S experienced Strength loss of 27%, 23%, and 20%, respectively. By 56 days, the disparity became more apparent, and HSC-C, HSC-FA, and HSC-S experienced significant strength loss of 43%, 34%, and 31%, respectively.

Similarly, the compressive strength results for concrete specimens (HSC-C, HSC-FA, and HSC-S), cured in water for 28 days and exposed to an acid solution for 0, 28, and 56 days, is presented in Fig. 7. At 28 days, there was no significant difference in strength loss between HSC-FA and HSC-S, with strength loss of 21% and 24%, respectively. However, HSC-C exhibited the most substantial strength loss at 32%. After 56 days of acid exposure, HSC-C, HSC-FA, and HSC-S suffered strength loss of 48%, 32%, and 38%, respectively. Notably, HSC-C consistently exhibited a higher percentage strength loss compared to HSC-FA and HSC-S at all exposure periods. HSC-S specimens exhibited the best performance when cured for 3 days and exposed to acid for 56 days, while HSC-FA specimens exhibited the best performance when cured for 28 days and exposed to acid for 56 days, as indicated in Table 8.

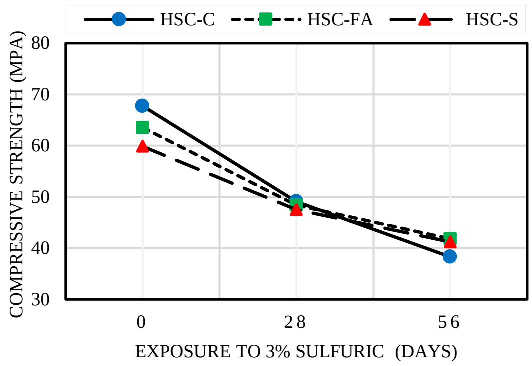

Fig.6 Acid impact on compressive strength in 3-day-cured HSC specimens.

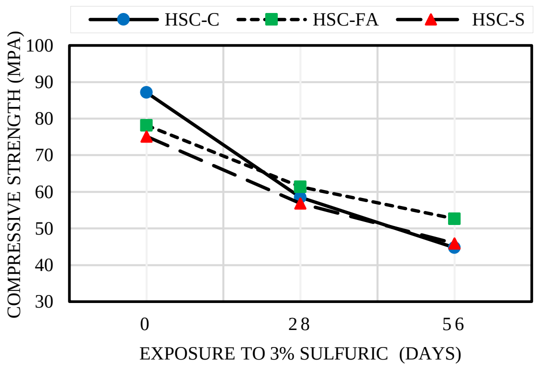

Fig.7 Acid impact on compressive strength in 28-day-cured HSC specimens.

Table 8: Compressive Strength Reductions in HSC

Curing Duration (days)		3	3	28	28
Acid Exposure Duration (days)		28	56	28	56
HSC-C (Control)	Strength % loss	27.5	43.5	32.9	48.7
HSC-FA	Strength % loss	23.8	34.2	21.5	32.7
HSC-S	Strength % loss	20.6	31.1	24.3	38.9
HSC-C and HSC-FA % Difference		14.4	23.9	41.9	39.3
HSC-C and HSC-S % Difference		28.7	33.2	30.1	22.4

3.4. Splitting Tensile Strength Loss

The results of splitting tensile strength loss for specimens from the mixtures (HSC-C, HSC-FA, and HSC-S), cured in water for 3 days and exposed to acid attack for 0, 28, and 56 days, is presented in Fig. 8. After 28 days of exposure, HSC-C, HSC-FA, and HSC-S exhibited loss in strength of 23%, 19%, and 17%, respectively. Following 56 days of acid exposure, HSC-C, HSC-FA, and HSC-S showed strength loss of 39%, 31%, and 29%, respectively. The results indicate that the strength loss between mixtures became slightly more noticeable after 56 days of exposure.

Figure 9 shows the splitting tensile strength loss results for specimens from mixtures HSC-C, HSC-FA, and HSC-S cured in water for 28 days and exposed to the acid solution for 0, 28, and 56 days. At 28 days of exposure, HSC-C, HSC-FA, and HSC-S exhibited strength loss of 26%, 18%, and 18%, respectively. After 56 days of exposure to acid, HSC-C, HSC-FA, and HSC-S exhibited strength loss of 41%, 30%, and 28%, respectively. The results highlight that HSC-C consistently demonstrated a higher percentage strength loss compared to HSC-FA and HSC-S at all exposure periods. Meanwhile, HSC-FA and HSC-S specimens exhibited the minimal strength loss when cured for 3 and 28 days and exposed to acid, with no significant differences between them, as opposed to HSC-C specimens, as indicated in Table 9.

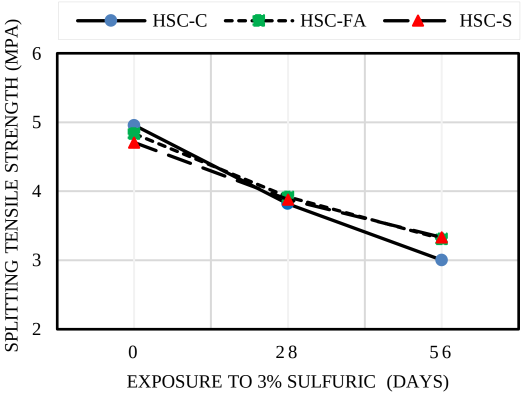

Fig.8 Acid impact on splitting tensile strength in 3-day-cured HSC specimens.

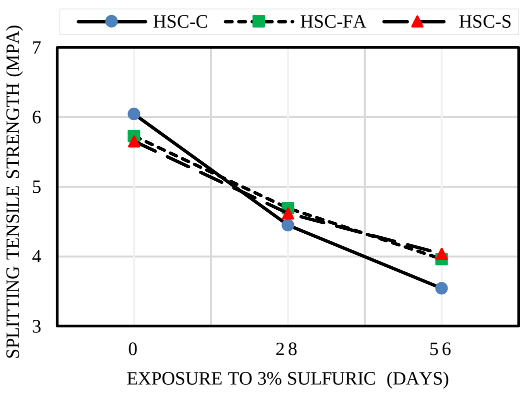

Fig 9. Acid impact on splitting tensile strength in 28-day-cured HSC specimens.

Table 9: Splitting tensile strength Reductions in HSC

Curing Duration (days)		3	3	28	28
Acid Exposure Duration (days)		28	56	28	56
HSC-C (Control)	Strength % Loss	23.03	39.46	26.38	41.39
HSC-FA	Strength % Loss	18.98	31.52	18.09	30.83
HSC-S	Strength % Loss	17.55	29.23	18.31	28.59
HSC-C and HSC-FA % Difference		19.3	22.4	37.3	29.2
HSC-C and HSC-S % Difference		27.0	29.8	36.1	36.6

3.5. Weight Loss

Figure 10 represents the weight loss of the HSC specimens cured for 3 days and immersed in the acid solution for 0, 28, and 56 days. HSC-C specimens experienced an average weight loss of 12% after 28 days, increasing to 17% after 56 days. HSC-FA specimens showed slightly lower weight loss, with an average of 9% after 28 days and 14% after 56 days. HSC-S exhibited a similar trend to HSC-FA, with an average weight loss of 7% after 28 days and 13% after 56 days.

Figure 11 represents the weight loss of the HSC specimens cured for 28 days and immersed in the acid solution for 0, 28, and 56 days. HSC-C specimens experienced an average weight loss of 10% after 28 days, increasing to 14% after 56 days. HSC-FA specimens showed slightly lower weight loss, with an average of 6% after 28 days and 10% after 56 days. HSC-S exhibited a similar trend to HSC-FA, with an average weight loss of 7% after 28 days and 11% after 56 days.

From Table 10, the results show that HSC-S specimens cured for 3 days, and HSC-FA specimens cured for 28 days resulted in less weight loss compared to the HSC-C specimens.

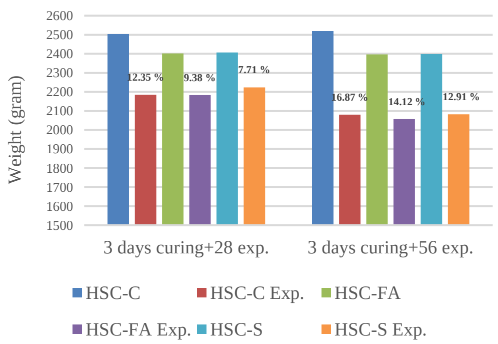

Fig.10 Acid effects on weight in 3-day-cured HSC specimens.

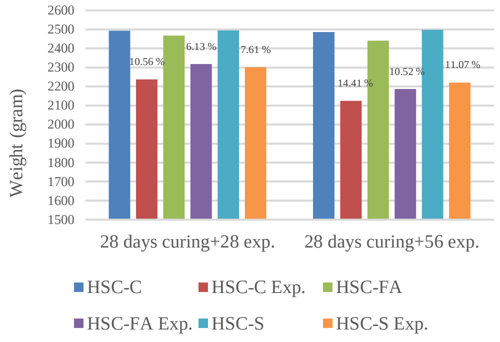

Fig.11 Acid effects on weight in 28-day-cured HSC specimens.

Table 10: Comparison of Weight Loss Across Mixtures

Curing Duration (days)		3	3	28	28
Acid Exposure Duration (days)		28	56	28	56
HSC-C (Control)	Weight % Loss	12.35	16.87	10.56	14.41
HSC-FA	Weight % Loss	9.38	14.12	6.13	10.52
HSC-S	Weight % Loss	7.71	12.91	7.61	11.07
HSC-C and HSC-FA % Difference		27.3	17.7	53.1	31.2
HSC-C and HSC-S % Difference		46.3	26.6	32.5	26.2

3.6. Discussion

The results show that both fly ash (FA) and ground granulated blast-furnace slag (GGBS) enhance the workability of high-strength concrete (HSC). FA reduces water demand, improves workability without affecting the water-to-binder ratio or superplasticizer dosage, attributed to its spherical shape, smooth texture, and fine particle size [26, 27]. GGBS also enhances workability through its smooth, dense surface, absorbing less water during mixing [26, 28].

Notable differences in acid resistance are observed among three HSC mixtures. HSC-C, incorporating silica fume without additional supplementary cementitious materials (SCMs), exhibits lower resistance to acid attacks compared to mixtures with GGBS or FA. This difference is evident in the specimens within both cured periods of 3-day and 28-day. The inferior acid resistance of HSC-C is attributed to its higher cement content, rendering it more vulnerable to acid attacks, while the incorporation of supplementary cementitious materials (SCMs) at 25% of the cement weight positively influences acid resistance.

The GGBS-containing mixture (HSC-S) demonstrates significant improvements under acid exposure, with minimal detrimental effects on weight loss, compressive strength, and tensile strength, especially in the 3-day water-cured group. The enhanced acid resistance of HSC-S is linked to reduced voids and pore size achieved through GGBS inclusion, leading to lower porosity [29-31]. As hydration progresses, the precipitation of more calcium hydroxides forms calcium silicate hydrate (CSH), filling pores, enhancing strength, chemical resistance, and refining pore size [32]. Concrete with GGBS content generally exhibits good resistance to acid attack during both early and later stages of development due to its denser structure and reduced permeability [33, 34].

On the other hand, the mixture containing fly ash (HSC-FA) exhibits a slower rate of hydration [35, 36], resulting in weaker acid resistance during the initial stages of concrete development. This delayed reaction of fly ash particles contributes to diminished acid resistance. Moreover, at early ages, fly ash concrete shows lower levels of calcium silicate hydrate gel (C-S-H) and higher porosity, making it less resistant to sulfuric acid attack [37, 38]. Over time, the presence of fly ash contributes to increased C-S-H formation, reducing interconnected voids as the binder material hydrates. Consequently, decreased capillary and gel pores, along with reduced interconnected voids due to fine particles [37, 39], collectively enhanced the strength and resistance of HSC-FA against acid for the group of specimens cured for 28 days.

4. CONCLUSIONS

1- Exposure to sulfuric acid caused surface erosion on HSC specimens, with severity increasing over time, leading to peeling and exposed aggregates after 56 days of exposure.

2- The incorporation of supplementary cementitious materials (SCMs), such as Fly Ash and GGBS, improved the workability of HSC compared to the control mix (HSC-C).

3- All HSC mixtures experienced a percentage of compressive strength loss upon acid exposure, with HSC-C exhibiting the highest decrease at all exposure durations.

4- Similar to compressive strength, all mixtures showed tensile strength loss due to acid exposure. HSC-C again suffered the most significant decrease, while HSC-FA and HSC-S displayed minimal loss with no significant difference between them.

5- HSC-C specimens lost the most weight upon acid exposure, with HSC-S cured for 3 days and HSC-FA cured for 28 days resulting in the least percentage of weight loss.

6- GGBS significantly improved acid resistance, especially in the 3-day cured group (HSC-S), while the mixture containing fly ash (HSC-FA) initially showed lower acid resistance in early concrete development. However, its presence contributed to improved strength and resistance against acid over a 28-day curing period.

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الخصائص الفيزيائية والميكانيكية للخرسانة عالية المقاومة الحاوية على مواد إسمنتية تكميلية ومعرضة لهجوم حمضي

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الملخص

تبحث هذه الدراسة في مقاومة الخرسانة عالية القوة (HSC) للتعرض لحمض الكبريتيك، مع التركيز على إمكانية استخدامها كبديل للخرسانة العادية في صب أرضيات مخازن الأحماض والمواد الكيميائية، ومنهولات مجاري الصرف الصحي، وغيرها من المناطق المعرضة للحمض. يشكل الهجوم الكيميائي العدواني من الاحماض تهديدًا كبيرًا لمتانة الخرسانة وقوتها. تتناول الدراسة أيضًا تأثير المواد الأسمنتية التكميلية (SCMs) على تعزيز مقاومة HSC للهجوم الحمضي. في إطار هذه الدراسة، تم إعداد ست مخاليط من الخرسانة عالية القوة: خليطتان تحكم تحتويان على المكونات الرئيسية للخرسانة عالية القوة، وخليطتان تحتويان على 25% من استبدال الأسمنت، إحداهما باستخدام الرماد المتطاير من النوع F والأخرى باستخدام الخبث. ثلاثة خلطات عولجت في الماء لمدة 3 أيام، وأخرى علوجت في الماء لمدة 28 يوماً. تم غمر جميع المخاليط في محلول حمض الكبريتيك 3% لمدة 28 أو 56 يومًا. لتقييم تدهور الخرسانة، تم قياس قوة الضغط، وقوة الشد، وفقدان الوزن. أظهرت الدراسة أن التعرض لحمض الكبريتيك تسبب في تآكل كبير لسطح HSC. شهدت جميع مخاليط HSC فقدان القوة، وخاصة مزيج الخليط التحكم. أدى وجود الخبث إلى تعزيز مقاومة حمض HSC، خاصة بالنسبة للعينات المعالجة لمدة 3 أيام بالماء. بينما أدى وجود الرماد المتطاير إلى تعزيز مقاومة حمض HSC للعينات المعالجة لمدة 28 يومًا.

الكلمات الداله :

الهجوم الحامضي، تدهور الخرسانة ، الديمومة ، الخرسانة عالية القوة، حامض الكبريتيك.