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SUSTAINABLE DEVELOPMENT OF CONCRETE USING COAL BOTTOM ASH AND SILICA FUME

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ABSTRACT

This Paper presents the outcomes from the typical evaluation of blended cement incorporating silica fume as a cement substitute and coal bottom ash as a fine aggregate replacement. For this, concrete blocks of the respective mixes were cast, and tests such as the compaction factor test and slump cone test were performed on fresh concrete with coal bottom ash as a substitute material in terms of fine aggregates in percentages of 10%, 20%, 30%, 40%, and 50% to check the workability, while compressive strength, flexural strength, split tensile strength, and durability of concrete in acid attack were performed on hardened concrete. A concrete mix of grade M25 was investigated while preserving the water-binder ratio at 0.4. The results show that using silica fume as a cement substitute material yields promising, good results at 15%. Strength was slightly reduced by increasing the proportion of SF, however utilizing coal bottom ash boosted the strength to 15% while maintaining reasonable workability. Using regular Portland cement and pozzolonic Portland cement provides a better concept of how to employ cementitious materials. In this paper, these SF blocks are also evaluated for accelerated curing to demonstrate the difference between a normal and an accelerated one. The results displayed indicate that, due to the usage of silica fume, rapid curing produces good results when compared to regular curing.

Keywords:
Blended Concrete, Silica fume, Coal bottom ash, Strength, Workability, Durability

I. Introduction

Concrete is a potently used material throughout the globe because of its advantages like general availability of ingredients, usefulness in a longer duration and at excessive extreme environmental conditions. But with its popularity concrete causes high amount of adverse effects on environmental health. Cement is a greater source which causes aggravation of global warming. Production of cement in factories intensifies higher levels of CO_2 emission that is an alarming problem in present scenario. Along with the rapid industrialization there are situations where disposal of waste is another big issue. Now these issues can be sorted by making use of basic three R's, i.e. Repair, Reuse, Recycle. Hence many of the researchers had come up with ideas of using wastes that shows some pozzolonic activities. These are then used as supplementary cementitious materials. There are various types of supplementary cementitious material like silica flume, fly ash, GGBFS, Metakaolin, In this work, an extensive study using silica fume and coal ash is used as binary mix and experimental study is made to find out the affectivity of mixes so produced. Use of Pozolonic Portland cement (PPC) and Ordinary Portland Cement (OPC) is initiated. In the preparation and enhancement of cement-concrete, various types of admixtures are used in different forms like binary, ternary or quaternary blended concrete. Pozzolanic additives are the materials that improve the properties like strength, durability and impermeability. They are used either as partial substitutes or as an addition to the cement mix. The main components of pozzolanic additives are active SiO_2 in amorphous phase. Pozzolanic reaction is a simple acid-based reaction between calcium hydroxide ($Ca(OH)_2$) and silicium acid (H_4SiO_4). The work is regarded to achieve the following set of objectives:

1. To find the optimum proportion of silica fume that can be used as a replacement/ substitute material for cement in concrete.
2. To find the optimum strength of replacement/ substitute material for cement in concrete when there are cured in accelerated curing tank.

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3. To evaluate effect of coal ash by replacing the fine aggregates and hence checking for strength and durability parameters.

II. Materials and Methodology

A. Silica Fume

Silica fume is usually a byproduct of the reduction of high-purity quartz with coal in an electric arc furnace to create silicon or ferrosilicon alloy. functions as a pozzolan. In furnaces set at 3630°F, silica fumes out as an oxidized vapor. It is gathered in large fabric bags once it condenses. Condensed silica fume is then cleaned up and its particle size is controlled through processing. The use of silica fume reduces tensile and flexural strength while increasing compressive strength. This is important when silica fume concrete is used for road, flooring, and bridging applications.
While compressive strengths remain high, higher tensile strength may result in a thinner slab. As a result, it reduces the overall slab weight and price. Silica fume concrete has a significantly finer phase than conventional concrete and a good adherence to substrates. Using silica fume greatly improves bonding to steel fibers. Silica fume also improves the structure of the fiber-matrix interface while decreasing the interfacial zone's weakness, as well as the number and size of cracks.

According to research, adding silica fume reduces efflorescence because it has a more refined pore structure and consumes more calcium hydroxide. The corrosion resistance of the reinforcing steel is increased when untreated silica fume is added to concrete with steel reinforcement. Additionally, it improves the concrete's resilience to chemical attacks from acid, chloride, and sulfate. These result in a decrease in permeability. For the silica fume concrete to work at its best, concrete curing methods are required. Because free water is used to wet the silica fume's extensive surface area, bleeding is considerably reduced when using silica fume..

The freeze-thaw durability is increased by using air spaces, also known as air entrainment, as cushions to handle the variations in volume. The freeze-thaw durability of mortar is increased by the inclusion of silica fume..

Table. I. Physical and Chemical Properties Of silica fume

Physical property	**SILICA FUME**
Specific gravity	2.2
Mean grain size (µm)	0.15
Specific area cm2/gm	150000-300000
Colour	White
Chemical property	**SILICA FUME**
Silicon dioxide (SiO_2)	85
Calcium oxide (CaO)	0.2-0.8
Magnesium oxide (MgO)	0.2-0.8
Sodium oxide (Na_2O)	0.5-1.2

B. Coal Ash :

Concrete The by-product of burning coal is coal bottom ash (CBA). During pulverization, the rock debris that had filled the coal fissures is removed from the coal. About 20% of coal ash is coal bottom ash, with the remainder being fly ash. CBA is a granular by-product of coal-burning furnaces that is gritty and incombustible. It mostly consists of silica, alumina, and iron, with minor amounts of calcium, magnesium sulfate, and other materials. Similar to river sand in appearance and particle size distribution is CBA.

Table.II.A. Physical properties of CBA

Specific gravity	(O.D.)	1.3-2.5	2.3-2.7
	(S.S.D.)	1.8-2.7	
Dry bulk density (kg/m^3)		700-1600	1600-2000

Absorption (wt.%)	0.8-6.0	< 2.0
Porosity (vol.%)	5-13	< 4
Uncompact void content (vol.%)	30-50	< 35

Table.II.B. Chemical properties of CBA

Sample	CBA
Chemical Content	**%**
Silica dioxide (SiO_2)	53.80
Aluminum Trioxide (Al_2O_3)	18.10
Ferric Oxide (Fe_2O_3)	8.70
Calcium Oxide (CaO)	5.30
Titanium dioxide (TiO_2)	1.20
Carbon (C)	0.10
Potassium Oxide (K_2O)	0.85
Magnesia/Magnesium Oxide (MgO)	0.58
Strontium oxide (SrO)	0.35
Phosphorus pentoxide (P_2O_5)	0.29
Sulfur trioxide (SO_3)	0.90
Barium oxide (BaO)	0.18
Zirconium dioxide (ZrO_2)	0.15
Sodium superoxide (Na_2O)	0.17

Table.II.C. Physical properties of CBA

Material	Aggregates 10mm	Aggregates 20mm	Sand	Bottom ash
Fineness Modulus	6.46	6.94	3.63	2.73
Specific Gravity	2.70	2.60	2.64	1.89
Water Absorption	0.56	0.61	1.01	10.2

C. Concrete Mixes

In this study, the early age properties of fresh concrete and mechanical performance and tensile strength of hardened concrete were examined. All tests were conducted using the following sample groups:

1. Conventional concrete of general mix using PPC and OPC each.
2. OPC is replace with 5%, 10%, 15%, 20% , 25% SF
3. PPC is replaced with 5%, 10%, 15%, 20% , 25% SF
4. Fine aggregate is replace with 10%, 20% , 30%, 40%, 50% CBA with best above combination
5. Blocks prepared are tested for accelerated curing and compared with normal curing.
6. Each of the above samples are tested for workability in case of CBA, compressive strength, flexural strength and chemical attack tests.

III. Results & Discussion

A. Curing is the process of controlling the rate and extent of moisture lost from concrete during cement hydration. In order to obtain good quality concrete an appropriate mix must be followed by curing in a suitable environment during the early stages of hardening. Curing must be undertaken for a reasonable period of time if concrete is to achieve its potential strength and durability.

Following are few different methods of curing:

a) Conventional Curing: The conventional curing involves dipping the specimens in water at 25˚C at the end of 24 hours of casting after allowing for air drying.

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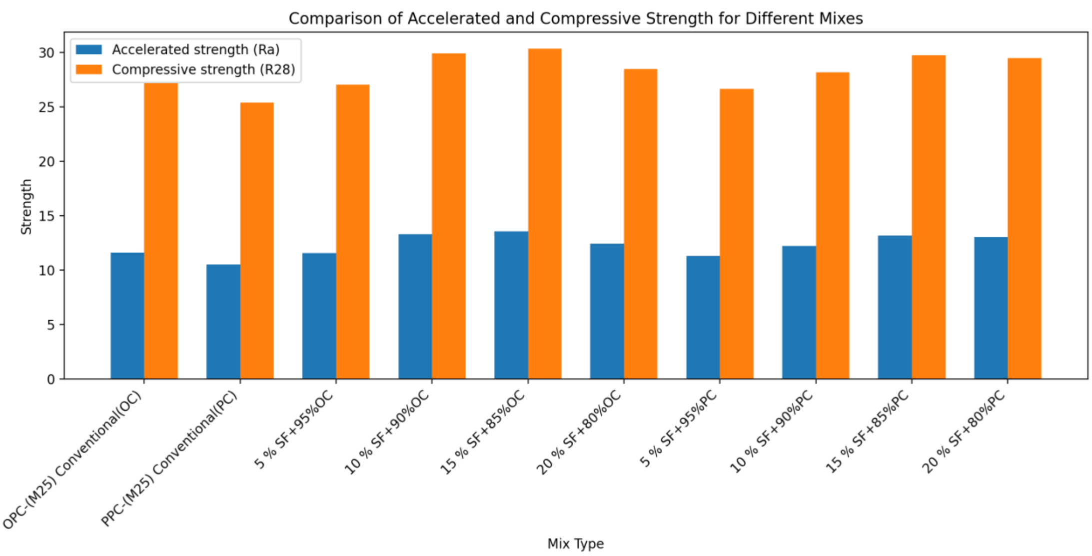
b) Accelerated Curing by warm water method: After the specimens have been made they shall be left to stand undisturbed in their moulds in a place free from vibration at a temperature of 25 ± 2˚C for at least one hour, prior to immersion in the curing tank. The time between the addition of water to the ingredients and immersion of the test specimens in the curing tank shall be at least 11 hours but shall not exceed 31 hours. The specimens in their moulds shall be gently lowered into the curing tank and shall remain totally immersed at 55 ± 2˚C for a period of not less than 19 hours 50 min. The specimens shall then be removed from the water, marked for identification, removed from the moulds and immersed in the cooling tank at 27 ± 2˚C before the completion of 20 hours 10 minutes from the start of immersion in the curing tank. They shall remain in the cooling tankfor a period of not less than one hour.

c) Accelerated curing by boiling water method: After preparing the specimens, store them in a vibration-free area with at least 90% humidity at 27 ± 2°C for 23 hours ± 15 minutes. Then, gently immerse them in the curing tank with water at boiling temperature (100°C at sea level) for 31 hours ± 5 minutes. Ensure the water temperature does not drop more than 3°C and returns to boiling within 15 minutes. After curing, remove the specimens, unmold, and cool them in a tank at 27 ± 2°C for 2 hours. The final strength, R28, is calculated as R28 = 8.09 + 1.64 Ra, where Ra is the accelerated strength.

Table.III. Concrete Mixes strength for Accelerated Curing

Sr No	Mix	Accelerated strength (Ra)	Compressive strength (R_{28})
1	OPC-(M25) Conventional(OC)	11.63	27.163
2	PPC-(M25) Conventional(PC)	10.54	25.376
3	5 % SF+95%OC	11.56	27.048
4	10 % SF+90%OC	13.29	29.886
5	**15 % SF+85%OC**	**13.57**	**30.345**
6	20 % SF+80%OC	12.42	28.459
7	5 % SF+95%PC	11.31	26.638
8	10 % SF+90%PC	12.23	28.147
9	**15 % SF+85%PC**	**13.19**	**29.722**
10	20 % SF+80%PC	13.03	29.459



Graph No1 -Comparison of Accelerated and Compressive Strength For Different Mixes

Here is the graph displaying both the Accelerated Strength (Ra) and Compressive Strength at 28 days (R28) for each mix. This visual comparison helps highlight the strength trends across different percentages of Silica Fume (SF) replacement.

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Discussions

1. Impact of Silica Fume (SF) on Strength-

1. Adding SF enhances both the accelerated (Ra) and 28-day compressive strengths for both Ordinary Portland Cement (OPC) and Portland Pozzolana Cement (PPC) mixes.
2. For OPC, the compressive strength increases significantly up to 15% SF, reaching a peak strength at 15% SF with 30.345 MPa.
3. For PPC, a similar trend is observed, with the highest strength achieved at 15% SF (29.722 MPa).

2. Comparing OPC and PPC Mixes-

1. Generally, OPC-based mixes exhibit slightly higher strengths compared to PPC-based mixes at each SF percentage level.
2. The addition of SF enhances the performance of both cement types, but the effect is more pronounced in OPC mixes. This could be due to the higher pozzolanic reactivity of SF, which complements OPC's hydration products, forming additional calcium silicate hydrate (C-S-H) gel that contributes to the strength.

3. Optimal Silica Fume Content-

Both OPC and PPC mixes show optimal compressive strength at 15% SF. Beyond this, strength slightly declines with 20% SF

4. Performance of Silica Fume Blended Mixes vs. Conventional Mixes:

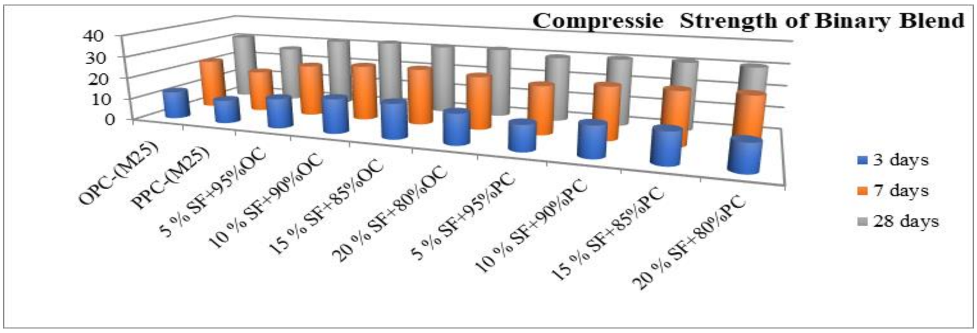
Mixes with 10–15% SF replacement outperform conventional mixes in terms of both Ra and R28 strengths. This highlights the effectiveness of SF as a partial replacement, improving the compactness and durability of concrete by reducing pore sizes and enhancing the matrix density..

B. Compressive Strength behavior of blended cement concrete.

The specimens were tested under UTM (100tons capacity) at 3, 7, 28 days respectively for binary blended cement and also for replacement of fine aggregates with coal bottom ash to check the strength comparison. The below tables shows the results in regards to compression tests conducted.

Table.IV. A. Compressive strength test results for replacement in cement

Sr No	Mix	Strength of concrete(N/mm2)		
		3 days	7 days	28 days
1	OPC-(M25) Conventional(OC)	12.6	22.7	31.2
2	PPC-(M25) Conventional(PC)	10.63	19.07	26.36
3	5 % SF+95%OC	13.6	23.8	31.8
4	10 % SF+90%OC	15.7	25.4	32.3
5	**15 % SF+85%OC**	**15.9**	**25.7**	**31.9**
6	20 % SF+80%OC	13.9	24.2	32.1
7	5 % SF+95%PC	11.63	22.1	29.9
8	10 % SF+90%PC	13.85	23.9	30.8
9	**15 % SF+85%PC**	**14.03**	**24.1**	**31.1**
10	20 % SF+80%PC	12.33	24.3	30.7



Graph No 2- Compressive strength test results for replacement in cement

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Discussions -Based on the 3-day, 7-day, and 28-day compressive strength results with varying Silica Fume (SF) content:

1. **Early Strength Development (3 days):**

SF addition generally improves early strength, especially at 10-15% replacement levels. This effect is more pronounced in OPC mixes, where the strength rises from 12.6 N/mm² (control) to a peak of 15.9 N/mm² with 15% SF.

2. **7-Day Strength Performance:**

Both OPC and PPC mixes show a strength increase at 10-15% SF, with OPC reaching 25.7 N/mm² and PPC 24.1 N/mm² at 15% SF. The accelerated pozzolanic reaction of SF likely contributes to this improvement.

3. **28-Day Strength Trend:**

The highest strength occurs around 10-15% SF for both cement types, showing an optimal level before performance levels out. OPC achieves a slight peak at 32.3 N/mm² (10% SF), while PPC reaches 31.1 N/mm² (15% SF).

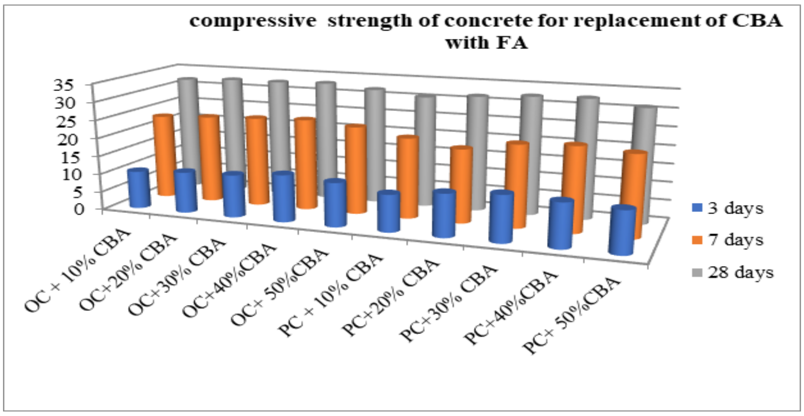
4. **Optimal SF Content:**

Overall, 10-15% SF provides optimal strength improvement across all curing ages. Beyond this, gains taper off, suggesting that 10-15% SF replacement strikes a balance between enhanced strength and cement content.

5. **Summary**- SF improves compressive strength at early, mid, and later stages, with 10-15% replacement generally showing the best results.

Table. IV. B. Compressive strength test results for replacement in fine aggregates

Sr No	Mix	Strength of concrete(N/mm^2)		
		3 days	7 days	28 days
1	OC + 10% CBA	10.36	23.36	32.03
2	OC+20% CBA	11.24	24.03	32.63
3	OC+30% CBA	11.63	24.56	32.66
4	**OC+40%CBA**	**12.85**	**25.02**	**33.01**
5	OC+ 50%CBA	11.97	23.98	31.97
6	PC + 10% CBA	10.06	21.93	30.66
7	PC+20% CBA	11.63	20.03	31.63
8	**PC+30% CBA**	**12.58**	**22.87**	**32.68**
9	PC+40%CBA	11.96	22.97	32.43
10	PC+ 50%CBA	11.36	22.01	31.09



Graph No 3. Compressive strength test results for replacement in fine aggregates

Discussions -

1. Early Strength Development (3 days): CBA replacement generally improves early strength in OPC (OC) mixes, peaking at 12.85 N/mm² with 40% CBA. PPC mixes (PC) show a similar trend, though with slightly lower values compared to OPC.

2. 7-Day Strength Performance: Strength continues to improve with increased CBA in OPC, reaching 25.02 N/mm² at 40% CBA. PPC shows more variability, achieving its highest at 22.97 N/mm² with 40% CBA.

3. 28-Day Strength Trend:

The highest 28-day strength for OPC is 33.01 N/mm² at 40% CBA. For PPC, the peak occurs with 30% CBA at 32.68 N/mm², after which the strength slightly declines.

4. Optimal CBA Content:

In both OPC and PPC mixes, 30-40% CBA yields optimal performance, especially in 28- day strength, enhancing the overall durability and strength.

5. **Summary**,- replacing fine aggregates with 30-40% CBA optimizes strength, especially in OPC mixes, indicating an effective use of CBA up to this range.

C. Flexural and Split-tensile strength behavior of blended cement:

Table.V. A Flexural and Split-tensile strength test results for replacement in cement

Sr No	Mix	Flexural Strength(N/mm²)	Split Tensile Strength(N/mm²)
1	OPC-(M25) Conventional (OC)	6.19	4.157
2	PPC-(M25) Conventional (PC)	5.49	3.287
3	5 % SF+95%OC	6.03	4.16
4	10 % SF+90%OC	5.96	4.54
5	**15 % SF+85%OC**	**6.59**	**4.67**
6	20 % SF+80%OC	6.92	3.86
7	5 % SF+95%PC	5.93	3.96
8	**10 % SF+90%PC**	**5.23**	**4.1**
9	15 % SF+85%PC	4.87	3.75
10	20 % SF+80%PC	5.02	3.56

Discussions –

1. **Flexural Strength**: In OPC, flexural strength peaks at 20% SF (6.92 N/mm²), while PPC achieves lower flexural values overall.
2. **Split-Tensile Strength**: OPC shows higher split-tensile strength, with the best result at 15% SF (4.67 N/mm²), suggesting improved tensile resistance.
3. **SF Content Impact**: 15-20% SF yields optimal flexural and split-tensile performance in OPC, while PPC performs best with lower SF levels.

Table.V. B Flexural and Split-tensile strength test results for replacement in fine aggregates

Sr No	Mix	Flexural strength(N/mm²)	Split Tensile Strength(N/mm²)
1	OC + 10% CBA	3.64	4.67
2	OC+20% CBA	3.52	3.86
3	OC+30% CBA	3.56	3.96
4	OC+40%CBA	3.34	4.1
5	OC+ 50%CBA	3.44	3.75
6	PC + 10% CBA	3.26	3.36
7	PC+20% CBA	3.29	4.16
8	PC+30% CBA	3.16	3.69

9	PC+40%CBA	3.01	3.36
10	PC+ 50%CBA	2.56	2.94

Discussions –

1. **Flexural Strength**: Flexural strength decreases as CBA content increases, with the highest value at 10% CBA for both OPC (3.64 N/mm²) and PPC (3.26 N/mm²).
2. **Split-Tensile Strength**: In OPC mixes, split-tensile strength peaks at 10% CBA (4.67 N/mm²), indicating optimal tensile performance at lower CBA levels.
3. **Effect of Higher CBA**: At CBA contents above 30%, both flexural and split-tensile strengths decrease, showing diminishing returns.
4. **OPC vs. PPC**: OPC mixes generally outperform PPC mixes in both flexural and split-tensile strengths at each CBA level.
5. **Optimal CBA Level**: The best balance of strength is achieved around 10-20% CBA, especially in OPC mixes, supporting limited replacement for optimal performance.

D. Workability of concrete-

Table.VI. Workability test results for replacement in fine aggregates

Sr No	Mix	Slump of Concrete (mm)	Compaction Factor	Workability
1	OC + 10% CBA	87	0.86	Medium
2	OC+20% CBA	91	0.886	Good
3	OC+30% CBA	90	0.889	Good
4	OC+40%CBA	99	0.91	Good
5	OC+ 50%CBA	119	0.97	High
6	PC + 10% CBA	81	0.84	Low
7	PC+20% CBA	77	0.823	Low
8	PC+30% CBA	71	0.803	Low
9	PC+40%CBA	63	0.86	Medium
10	PC+ 50%CBA	59	0.92	Good

Discussions –

1. **Slump Trends**: In OPC (OC) mixes, slump increases with higher CBA, peaking at 50% CBA (119 mm), indicating enhanced workability.
2. **Compaction Factor**: OPC mixes generally show higher compaction factors, with values increasing as CBA content rises.
3. **Workability Levels**: OPC mixes shift from medium to high workability with higher CBA, while PPC (PC) mixes remain in the low to medium range, even at 50% CBA.
4. **Effect of Higher CBA**: Higher CBA replacement (40-50%) improves workability significantly in OPC mixes, suitable for applications needing easier placement.
5. **OPC vs. PPC**: OPC mixes achieve better workability than PPC at each CBA level, with PPC mixes showing limited improvement in slump and compaction factor.

E. Loss of mass and strength when tested for durability:

For the purpose of calculating the mass loss owing to the acid assault, concrete cubes 150 mm in size were cast. The produced cubes were cured in water for 28 days before spending the following 30 days submerged in 5%HCl solutions. For the purpose of determining the mass loss resulting from the deterioration of concrete specimens, the initial mass and the mass of concrete specimens after the 4-week immersion time were measured. For evaluation, the average value of three samples was taken into account. After 4 weeks of immersion, the compressive strength test was performed on each specimen in both solutions. Three samples were examined and their average values from each testing period were recorded.

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Table VII. Loss of Weight results for replacement in cement

Sr. No.	Mix	Weight of Concrete blocks before immersion in acid solution	Weight of Concrete blocks after 30 days immersion in acid solution	Loss of mass of concrete due to acidic reaction
		(kg)	(kg)	(%)
1	OPC-(M25)	8.75	8.13	7.085
2	PPC-(M25)	8.56	8.18	4.439
3	5 % SF+95%OC	8.6	8.23	4.302
4	10 % SF+90%OC	8.55	8.195	4.152
5	15 % SF+85%OC	8.5	8.2	3.529
6	20 % SF+80%OC	8.65	8.31	3.931
7	5 % SF+95%PC	8.56	8.18	4.439
8	10 % SF+90%PC	8.45	7.96	5.798
9	15 % SF+85%PC	8.53	7.89	7.503
10	20 % SF+80%PC	8.62	8.02	6.961

Discussions –

1. **Acid Resistance in OPC vs. PPC**: OPC shows a higher initial mass loss (7.085%) compared to PPC (4.439%), indicating better acid resistance in PPC-based mixes.
2. **Effect of Silica Fume (SF) in OPC**: In OPC mixes, adding SF improves acid resistance, with the best result at 15% SF (3.529% loss). SF's pozzolanic activity likely enhances concrete's density and reduces porosity, limiting acid attack.
3. **Effect of SF in PPC**: For PPC mixes, adding up to 5-10% SF shows moderate acid resistance, but losses increase beyond 10% SF, peaking at 15% SF (7.503%), possibly due to reduced cementitious content weakening the matrix.
4. **Optimal SF Content for Acid Resistance**: 15% SF replacement in OPC achieves the best acid resistance, while PPC is best with no more than 5% SF.
5. **Conclusion**: SF improves OPC's acid resistance effectively, but higher SF content in PPC mixes may diminish its acid resistance.

Table VIII. Loss of Strength results for replacement in Cement

Sr. No.	Mix	28 days compressive strength on normal curing (N/mm^2)(f_{cw})	Compressive strength of concrete cubes immersed in acidic solution of 5% HCl	Loss of strength of concrete due to acidic reaction
			(N/mm^2) (f_{ca})	(%)
1	OPC-(M25)	31.2	23.36	25.128
2	PPC-(M25)	26.36	18.36	30.349
3	5 % SF+95%OC	31.8	25.93	18.459
4	10 % SF+90%OC	32.3	26.56	17.771
5	15 % SF+85%OC	31.9	28.63	10.251
6	20 % SF+80%OC	32.1	28.45	11.371
7	5 % SF+95%PC	29.9	22.59	24.448
8	10 % SF+90%PC	30.8	24.69	19.838
9	15 % SF+85%PC	31.1	27.13	12.765

10	20 % SF+80%PC	30.7	26.71	12.997

Discussions

1. **Acid Resistance in OPC vs. PPC**: OPC shows better resistance to strength loss in acidic conditions (25.13% loss) than PPC (30.35% loss), indicating OPC performs slightly better in acidic environments.
2. **Impact of Silica Fume (SF) on OPC**: In OPC mixes, adding SF improves acid resistance, with the best performance at 15% SF, showing only a 10.25% strength loss.
3. **Impact of SF on PPC**: PPC with SF also benefits from improved acid resistance, particularly at 15% SF (12.77% loss), though PPC mixes generally have a higher percentage of strength loss compared to OPC.
4. **Optimal SF Content for Acid Resistance**: For both OPC and PPC, 15-20% SF provides optimal acid resistance, significantly reducing strength loss compared to lower SF percentages.
5. **Conclusion**: SF effectively enhances acid resistance in both OPC and PPC mixes, with the most notable improvements at 15% SF replacement, minimizing strength deterioration in acidic conditions.

Table IX Loss of Weight results for replacement in Aggregate

Sr No	Mix	Weight of Concrete blocks before immersion in acid solution	Weight of Concrete blocks after 30 days immersion in acid solution	Loss of mass of concrete due to acidic reaction
		(kg)	(kg)	(%)
1	OC + 10% CBA	7.98	7.23	9.398
2	OC+20% CBA	7.92	7.16	9.596
3	OC+30% CBA	7.88	7.03	10.787
4	OC+40%CBA	8.01	7.22	9.863
5	OC+ 50%CBA	8.35	7.37	11.737
6	PC + 10% CBA	8.01	7.19	10.237
7	PC+20% CBA	8.15	7.21	11.534
8	PC+30% CBA	8.23	7.34	10.814
9	PC+40%CBA	8.27	7.31	11.608
10	PC+ 50%CBA	8.31	7.54	9.266

Discussions –

1. **Acid Resistance**: The results indicate varying resistance to acid attack based on the percentage of Coal Bottom Ash (CBA) used, with higher CBA percentages generally leading to increased mass loss.
2. **Optimal Replacement Level**: The 10% CBA replacement shows the least mass loss, suggesting it may offer better acid resistance compared to higher replacement levels.
3. **Decreasing Performance**: Mass loss increases with higher CBA content (e.g., OC + 50% CBA shows the highest loss), indicating that excessive CBA may compromise durability in acidic environments.
4. **Comparison of Mix Types**: Both Ordinary Concrete (OC) and PPC mixes demonstrate similar trends, but specific percentages of CBA lead to different loss rates, hinting at the influence of the base mix on acid resistance.

Table VIII. Loss of Strength results for replacement in Aggregate

Sr No	Mix	28 days compressive strength on normal curing	Compressive strength of concrete cubes immersed in acidic solution of 5% HCl	Loss of strength of concrete due to acidic reaction
		$(N/mm^2)(f_{cw})$	(N/mm^2) (f_{ca})	(%)
1	OC + 10% CBA	32.03	24.92	22.198

2	OC+20% CBA	32.63	26.23	19.614
3	OC+30% CBA	32.66	25.93	20.606
4	OC+40%CBA	33.01	29.53	10.542
5	OC+ 50%CBA	31.97	27.63	13.575
6	PC + 10% CBA	30.66	24.03	21.624
7	PC+20% CBA	31.63	25.31	19.981
8	PC+30% CBA	32.43	26.82	17.299
9	PC+40%CBA	32.68	28.93	11.475
10	PC+ 50%CBA	31.09	27.13	12.737

Discussions -

1. **Acid Resistance in OPC vs. PPC**: OPC (OC) mixes generally show lower strength loss in acidic conditions than PPC (PC) mixes, indicating better acid resistance in OPC.
2. **Optimal CBA Content**: Both OPC and PPC perform best at 40% CBA, showing the lowest strength loss (10.54% in OPC and 11.48% in PPC), suggesting 40% CBA as optimal for acid resistance.
3. **Higher CBA Impact**: Increasing CBA content up to 40% improves acid resistance, but performance slightly declines at 50% CBA, indicating a possible limit for effective replacement.
4. **Best Performance Mixes**: OPC with 40% CBA achieves the lowest strength loss, indicating that CBA enhances durability against acidic attacks up to this level.
5. **Conclusion**: Replacing fine aggregates with 30-40% CBA enhances acid resistance in concrete, making it more durable in acidic environments, especially in OPC mixes.

IV. **Conclusion**

1. **Optimal Replacement**: 15-20% SF in OPC and 30-40% CBA as fine aggregate replacement offer the best balance of strength, durability, and acid resistance.
2. **Strength Gains**: SF boosts compressive, flexural, and tensile strengths in OPC, while CBA enhances compressive and flexural strengths in both OPC and PPC.
3. **Workability**: CBA significantly improves workability, especially at 40-50%, making placement easier, while SF reduces it slightly, needing adjustments.
4. **Acid Resistance**: Both SF and CBA reduce acid-induced mass and strength loss, with best results at 15-20% SF and 30-40% CBA.
5. **Sustainability**: Using SF and CBA as replacements enhances concrete performance and supports environmentally sustainable construction practice

V. REFERENCES

[1] A I F Ahmad Maliki, S Shahidan, N Ali1, N I R Ramzi Hannan, S S Mohd Zuki, M H W Ibrahi, M A Mohammad Azmi and M. Abdul Rahim- " Compressive and tensile strength for concrete containing coal bottom ash", IOP Conferenece series MSE 271(2017)

[2] Sudhansu Tak , Priyanshu Gupta , Alok Kumar , A. Sofi , Chin Mei Yun "Effect of using silica fume as a partial replacement of cement in concrete" Materials today proceedings 2023, https://doi.org/10.1016/j.matpr.2023.04.205

[3] Lakshmisupriya Kanamarlapudi, Krishna Bhanu Jonalagadda , Durga Chaitanya Kumar Jagarapu, Arunakanthi Eluru, "Different mineral admixtures in concrete: a review "SN Applied Sciences (2020) 2:760 https://doi.org/10.1007/s42452-020-2533-6

[4] Tariq Ali , Abdul Salam Buller , Fahad ul Rehman Abro , Zaheer Ahmed , Samreen Shabbir , Ali Raza Lashari and Ghulam Hussain , "investigation on mechanical and durability properties of concrete mixed with silica fume as cementitious material and coal bottom ash as fine aggregate replacement material ", Buildings 2022, 12,44.https://doi.org/10.3390/buildings12010044

[5] Mardani-Aghabaglou, A Tuyan, M, Ramyar, K, "Mechanical and durability performance of concrete incorporating fine recycled concrete and glass aggregates", Mater. Struct. 2015, 48, 2629–2640.
[6] Singh, M, Siddique, R. "Effect of coal bottom ash as partial replacement of sand on workability and strength properties of concrete", J. Clean. Prod. 2016, 112, 620–630.
[7] Ngiseng Seav , Kyoung Su Kim , Jae Hoon Kim , Seung Woo Lee and Young Kyu Kim " Effects of Roller Compacted Concrete Incorporating Coal Bottom Ash as a Fine aggregate replacement Sustainability2023,15,11420. https://doi.org/10.3390/su151411420
[8] Vikas Srivastava1, V.C. Agarwal and Rakesh Kumar "Effect of Silica fume on mechanical properties of Concrete "J. Acad. Indus. Res. Vol. 1(4) September 2012
[9] Huai-Shuai Shang and Ting-Hua Yi "Freeze-Thaw Durability of Air-Entrained Concrete" The Scientific World Journal Volume 2013, Article ID 650791, 6 pages http://dx.doi.org/10.1155/2013/650791
[10] R.Selvapriya "Silica fume as Partial Replacement of Cement in Concrete" International Research Journal of Multidisciplinary Technovation /2019, 1(6), 325-333
[11] Amudhavalli, N. K. & Mathew, J "Effect of silica fume on strength and durability parameters of concrete". International Journal of Engineering Sciences & Emerging Technologies. 3 (1), 28-35-2012
[12] Kumar, R. Dhaka, J. "Review paper on partial replacement of cement with silica fume and its effect on concrete properties". International Journal for Technological Research in Engineering. 4,(1). 2016
[13] Gagandeep, Amanpreet Tangri, Vipasha Rishi , "Effect of Replacement of Cement by Different Percentages of Silica Fume" International Journal of Research in Advent Technology, Vol.6, No.5, May 2018
[14] Pradhan, D & Dutta, D. "Effects of Silica Fume in Conventional Concrete". International Journal of Engineering Research and Applications. 3(5). 2013
[15] Vikas Srivastava , Rakesh Kumar , V. C. Agarwal and P. K. Mehta, "Effect of Silica Fume on Workability and Compressive Strength of OPC "ConcreteJournal of . Environmemtal . Nanotechnology , *Vol. 3(3), 32-35, 2014*
[16] Bhanja, Shantanu, and Sengupta, Bratish "Optimum Silica Fume content and its Mod of Action on Concrete, ACI Materials Journal, 100(5), 407-412(2003).
[17] ACI, 234R-96, Guide for the Use of Silica Fume in Concrete", Reported by ACI, Committee, 234, 1-51 (1996).
[18] Neville, A.M. " Properties of Concrete". John Willey &Sons. INC. New York. USA. [13]. PP 711-713
[19] M.S Shetty, S.Chand 'Concrete technology, theory and practice' Tata McGrah Hill Company Ltd, New Delhi.
[20] IS-15388-2003 : Silica Fume-Specification
[21] IS: 10262-1982, Recommended Guidelines for Concrete Mix Design, Bureau of Indian Standards, New Delhi, India.
[22] IS: 1199-1959, Indian Standard Methods of Sampling and Analysis of Concrete, Bureau of Indian Standards, New Delhi, India