

Behaviour of Fly Ash-Based Geocomposites Incorporated with Pond Ash and Oyster shell Ash

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Abstract:

Geobinder is a viable ingredient in concrete that does not emit greenhouse gases during or after curing. In the scenario and a panorama of waste, exploitation, and eco-sustainable geopolymer block production, the viability of total substitution of cement incorporated with fly ash in geo-polymer blocks was investigated. Variations in characteristic parameters of ecological geocomposite related to different molar concentrations of alkaline catalysts were considered. The ideal molarity ratio predicted was 12 m. It was pragmatic that better characteristics were accomplished with geocomposite, which had a molarity of 12. Additionally, fly ash can substitute 100% cement without compromising the attributes of ecological geocomposites. The use of these blocks has the potential to significantly reduce CO₂ emissions.

Keywords: CO₂ emanation, Global warming, Fly ash, Ideal molarity, Crushed sand, Pond ash, Oyster shell ash

1. Introduction:

Cement is an inexhaustible binder material in all concrete applications all over the world. Construction is ongoing in all places, and due to this, the necessity for cement is amplified. To overcome this, fly ash has been used in place of cement. Large amounts of pollutants are emitted during cement production, causing environmental contamination. The process of making cement spills carbon dioxide into the environment. About one tonne of CO₂ escapes into the atmosphere for every tonne of cement produced. By considering that, we are utilizing fly ash as a binding ingredient for producing blocks along with alkaline solutions, which are named "Geo polymer composites." [1-4] As a result of this, we can decrease the requirement for cement and also diminish the emissions of pollutants into the atmosphere that are released by the cement industry.[5-7] As a by-product of thermal power plants, fly ash is the most prevalent industrial waste in the environment. [8-11]. Crushed sand is a viable substitute for conventional natural sand, and the texture of crushed sand bears a resemblance to that of conventional natural sand. Because of the extenuating threat of conventional natural sand utilization, crushed sand is being used as a viable substitution for river sand in the production of geocomposite and concrete. In this investigation, pond ash was utilized to as fine aggregate to replace crushed sand. [12-15]. When coal was burned in thermal power plants, intense heat was produced. This transforms the coal powder's clay minerals into a variety of fused, small elements that are mostly composed of aluminum silicate. [16-20]This waste by-product is partially surrogated for fine aggregate in geopolymer concrete from crushed sand [21-24]. Exploitation of oyster shells in the form of ash caused by contamination in the living

atmosphere can be condensed. [25-26]This exploitation of geopolymer blocks appreciably diminishes CO₂ emanation and shrinks pollution by greenhouse gases.

2. Materials and testing methods

The investigational validation of the prospects of surrogating cement in the composite shroud necessitates a prelude narrative and a qualitative properties investigation for standard and superfluous constituents. Geocomposite was produced using fly ash, crushed sand, pond ash, oyster shell ash and alkaline activators.

2.1. Fly ash

On-hand investigation engrosses the use of fly ash with class "F" grade as a binding ingredient in the geocomposites. Fly ash is drawn from a thermal power plant located in Mettur, Tamil Nadu. In this work, cement was substituted with fly ash in the geocomposite block. Table 1 gives the attributes of Class "F" grade fly ash.

Table 1 Characteristics of Fly Ash

Description	Fly Ash
Specific Gravity	2.185
Fineness	362 m ² /kg
SiO ₂	60.275%
Al ₂ O ₃	24.175%
Fe ₂ O ₃	4.125%
Al ₂ O ₃ +SiO ₂ + Fe ₂ O ₃	88.565%
Al ₂ O ₃	1.372%
Fe ₂ O ₃	2.75%
SO ₃	2.875
Alkali	2.675%
LOI	1.356%

2.2. Sodium Carbonate

In this investigation, sodium carbonate was exploited to replace liquid sodium hydroxide with fewer perilous alkali ingredients, with the added advantage of better mixing and handling progression. It will be a better ecological, environmentally durable, and sustainable ingredient since it has less embodied vigor when compared with sodium hydroxide. The chemical and physical attributes of the silicates are illustrated in Table 2.

Table 2: Physical and Chemical Attributes of Sodium Carbonate

Characteristics	Percentage by Mass
Density	2.55 g/cm ³
Na ₂ O	58.1%
NaCl	0.05%
Na ₂ SO ₄	0.15%
p ^H	10.57
Bulk density	1055 g/cm ³
Sieve analysis	
0.125-0.25mm	29.97%
0.065-0.125mm	34.97%
<0.065mm	34.95%
Boiling point	1600°C
Carbonate Na ₂ CO ₃	99.2%
Molarity	105.95

2.3. Sodium Silicate

Sodium silicate is presented in a fluid (gel) state and is referred to as "water glass" or "liquid glass." The proportion of sodium hydroxide to sodium silicate is maintained at 2.00 in this investigation. In industries, sodium silicate is employed as a binding substance. The manufacturer provides the chemical and physical attributes of the silicates, as illustrated in Table 3.

Table 3: Physical and Chemical Attributes of Sodium Silicate

Chemical Formula	Na ₂ SiO ₂
Na ₂ O	15.87%
SiO ₂	31.67%
H ₂ O	53.4%
Colour	Light yellow
Boiling Point	101° C
Molecular Weight	184.07 g
Specific Gravity	1.73

2.4. Potable Water

Potable water from the local area was used for the making and curing of geocomposite samples. Cast specimens were cured at room temperature using readily available potable water. The characteristics of the water used for geocomposite samples are shown in Table 4.

Table 4: Potable water characteristics

S.No	Parameter	Potable water	Permissible limit (IS 456-2000)
1.	pH	7.65	> 6
2.	TDS (mg/L)	1360	-
3.	Chloride (mg/L)	162	2000 (for PCC) 500 (for RCC)
4.	Sulphate (mg/L)	148	400

2.5. Fine Aggregate

To create Geo composite, crushed sand, pond ash, and oyster shell ash were blended as fine granules. Sieve analysis was conducted as per the modulus operandi, and the grain size distribution of the sample was used to determine test values. Gradation was performed by IS 383-1970. The outcome of sieve analysis results reveals that samples are coming within Zone II, other attributes such as specific gravity, fineness modulus, and water absorption were found and illustrated in Table 5.

Table 5 Characteristics of Fine Granules.

S.No	Characteristics	Crushed sand	Pond ash	oyster shell ash	IS Code
1.	Specific gravity	2.69	2.69	2.12	IS 2386: 1963 (Part 3)
2.	Fineness modulus	2.94	2.65	2.11	IS 2386: 1963 (Part 1)

3.	Water absorption (%)	0.92	0.92	6.22	IS 2386: 1963 (Part 3)
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2.6. Coarse Aggregate

20-mm angular aggregates were used as coarse aggregate for the production of the Geo composite. A sieve analysis test was done as per IS 2386 (Part 1) (1963). The physical characteristics of coarse aggregate were found is shown in Table 6.

Table 6. Characteristics of coarse aggregate

S.No	Characteristics	Test values	IS Code
1.	Specific gravity	2.70	IS 2386: 1963 (Part 3)
2.	Fineness modulus	6.37	IS 2386: 1963 (Part 1)
3.	Water absorption (%)	0.69	IS 2386: 1963 (Part 3)

The mix ID and materials

Table 7. Constituents needed per cum of geopolymer composite with diverse mix identities.

Mix Identity	Fly ash	crushed Sand	pond ash	Oyster shell ash	CA	Water	Na ₂ O ₃	Na ₂ SiO ₃	Molarity	% of pond ash	% of oyster shell ash	% of crushed sand
CS1	401.7	680.78	-	-	1264.75	101.7	317.85	317.85	6	-	-	100
CS2	401.7	680.78	-	-	1264.75	101.7	423.80	423.80	8	-	-	100
CS3	401.7	680.78	-	-	1264.75	101.7	529.75	529.75	10	-	-	100
CS4	401.7	680.78	-	-	1264.75	101.7	635.70	635.70	12	-	-	100
CS5	401.7	680.78	-	-	1264.75	101.7	741.65	741.65	14	-	-	100
PA20	401.7	544.62	136.16	-	1264.75	101.7	635.70	635.70	12	20	-	80
PA40	401.7	408.47	272.31	-	1264.75	101.7	635.70	635.70	12	40	-	60
PA60	401.7	272.31	408.47	-	1264.75	101.7	635.70	635.70	12	60	-	40
PA80	401.7	136.16	544.62	-	1264.75	101.7	635.70	635.70	12	80	-	20
PA100	401.7	0	680.78	-	1264.75	101.7	635.70	635.70	12	100	-	0
PA40 OSA10	401.7	340.39	272.31	68.08	1264.75	101.7	635.70	635.70	12	40	10	50
PA40 OSA20	401.7	272.31	272.31	136.16	1264.75	101.7	635.70	635.70	12	40	20	40

PA40 OSA30	401.7	204.23	272.31	204.23	1264.75	101.7	635.70	635.70	12	40	30	30
PA40 OSA40	401.7	136.16	272.31	272.31	1264.75	101.7	635.70	635.70	12	40	40	20
PA40 OSA50	401.7	68.08	272.31	340.39	1264.75	101.7	635.70	635.70	12	40	50	10

2.7. Alkaline activators

Sodium carbonate and sodium silicate are mixed in liquid form to get an activating solution at least 24 hours before use. An activator solution produced with a 0.50 mass ratio is used. Commercially available sodium carbonate is available in pellet form with 98–99% purity.

2.8. Crushed sand and pond ash blended to produce a geocomposite.

In the present exploration, pond ash was partially substituted for crushed sand in the ratios of 20%, 40%, 60%, 80%, and 100%.

2.9. Domination of Pond ash and oyster shell ash integrated geopolymer composite.

Optimal combination of pond ash and oyster shell ash

To calculate the prospective of blending an optimal proportion of pond ash and oyster shell ash with the diverse blending of oyster shell ash in geopolymer composites, the mix ID is designated as follows:

Table 8: Mix proportions of pond ash and oyster shell ash with mix ID

Mix ID	Description
PA40 OSA10	Pond ash 40% + 10% oyster shell ash
PA40 OSA20	Pond ash 40% + 20% oyster shell ash
PA40 OSA30	Pond ash 40% + 30% oyster shell ash
PA40 OSA40	Pond ash 40% + 40% oyster shell ash
PA40 OSA50	Pond ash 40% + 50% oyster shell ash

The most advantageous surrogate proportion of oyster shell ash with pond ash (40%) was predicted.

3. Testing method

According to IS 526:1987, 150x150x150 mm geocomposites were created for testing of compressive properties over 7 and 28 days in order to determine whether they could replace traditional geo-polymer composites. To determine the ideal ratio of sodium carbonate molarity in the geo composites, a sodium silicate solution was used in a random manner in order to exploit different molarities of 8 m, 10 m, 12 m, and 14 m of sodium carbonate.

3.1. Investigation of Hardened Geopolymer Composites.

3.1.1 Compressive Characteristics Test

The compressive characteristics of geo composite cubes measuring 150x150x150mm with crushed sand, pond ash, and oyster shells was determined as per the IS 516-1959 procedure. Three sets of samples were cast for each mixing ratio and each curing spell. To assess the compressive characterization variations of geopolymer composites, an average compressive characterization of three samples for each mixing ratio and curing spell was performed.

3.1.2. Flexural Characteristics Test

The flexural strength of geopolymer block prismatic samples of 100x100x500mm with crushed sand, pond ash, and oyster shells was determined as per the IS 516-1959 procedure.

Central point load was the method of loading that was utilized to ascertain the flexural characteristics. After 7 and 28 days of curing, the flexural properties of the geocomposite were evaluated. The outcomes of the tests were correlated with the standard geocomposite.

3.1.3 Half-cell Potential Test

In order to investigate the corrosion activity of steel embedded cylinders measuring 150 mm by 300 mm and embedded with a 20 mm steel rod, geocomposite containing crushed sand, pond ash, and oyster shells in various combinations was created and allowed to cure at room temperature for 28 days. On completion of curing, samples were engrossed in sodium chloride of 2.50% with a DC electric current of 12 V capacity. A voltmeter was connected to an electrode containing copper-copper sulphate and its potential divergence amid steel and geopolymer composites was determined. The outcome of the tests, steel rod corrosion activity, was determined and illustrated in Table 9.

Table 9. Half-cell potential range and corrosion percentage

Sl.No	Potential difference (mV)	probability of corrosion (ASTM C-876)
1.	<-180	8%
2.	>-180 to -400	52%
3.	> -400	88%

3.1.4. Acid resistance test

Geo composite with crushed sand, pond ash, and oyster shells in diverse combinations were attempted through acid resistance tests with a 150x150x150 mm specimen engrossed in a 2.50% H₂SO₄ solution, and resistance was determined for the geopolymer composite. Due to engrossing in sulphuric acid for 30, 60, 90, and 120 days, weight loss was predicted and analyzed.

4. Results and discussions

Geocomposite with crushed sand, pond ash, and oyster shells in diverse combinations were exploited and correlated with standard composite. By conducting diverse combination tryouts, optimal molarity was predicted for the target mean strength of 30 MPa.

4.1. Compressive characteristics of differences in geocomposite for diverse molarities

Figure1 shows the compressive characteristics of the geocomposite with crushed sand for various molarities. The impact of diverse molar proportions of activating solution on the compressive strength of geocomposite was studied. The CS4 specimen's peak compressive strength, evaluated at 28 days of age, was. 38.86 MPa. It is established that 12 was the ideal molarity percentage. According to the test results, increasing molarity significantly enhances compressive strength; nevertheless, once the ideal level was reached, the compressive strength of geopolymer composite decreased.

Figure 1. Compressive Characteristics for Diverse Molarities

The strength development at 28 days of age was comparable to that at 7 days. Its maximal compressive properties were found to be 30.09 MPa and 36.86 MPa, respectively, after 7 and 28 days of curing for 12 molarity.

4.2. Flexural characteristics of the divergence of Geo composite blocks for diverse molarity proportions

Geocomposite with crushed sand in diverse combinations were exploited and correlated with standard geocomposite for flexural characteristics, and an ideal flexural strength value was attained at 12 molarity. At 7 days, the average flexural strength of different molarity ratios ranges from 3.10 to 3.76 MPa, and at 28 days, it ranges from 4.22 to 4.92 MPa.

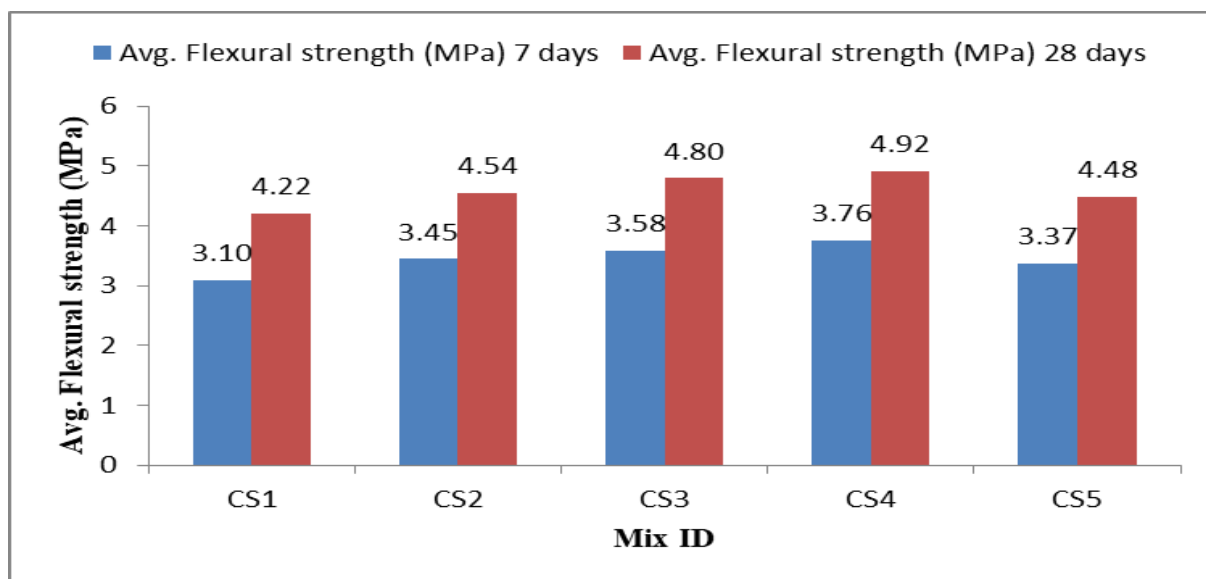


Figure 2. Flexural Characteristics for Diverse Molarities.

The strength development trend of flexural strength is identical to that of compressive strength. Details of the flexural character values of the geocomposite for different molarities are shown in Figure 2. The results of the experiment showed that the flexural strength of geopolymer composite at all ages up to 12M is improved by an increase in the molarity ratio. With a molarity of 12, the maximum flexural strength value of 4.80 MPa was achieved.

4.3.1 Compressive characteristics Disparity of crushed sand, pond ash, integrated geocomposite .

The compressive characteristic values of crushed sand-incorporated geocomposites are demonstrated in Figure 3. Crushed sand was partially substituted with pond ash, and the test results indicated that geocomposites gained higher compressive characteristics at 40% replacement of pond ash. Higher compressive characteristics values of 24.86 MPa and 36.67 MPa were attained at the end of 7 days and 28 days of curing, respectively, for 40% crushed sand replacement with pond ash.

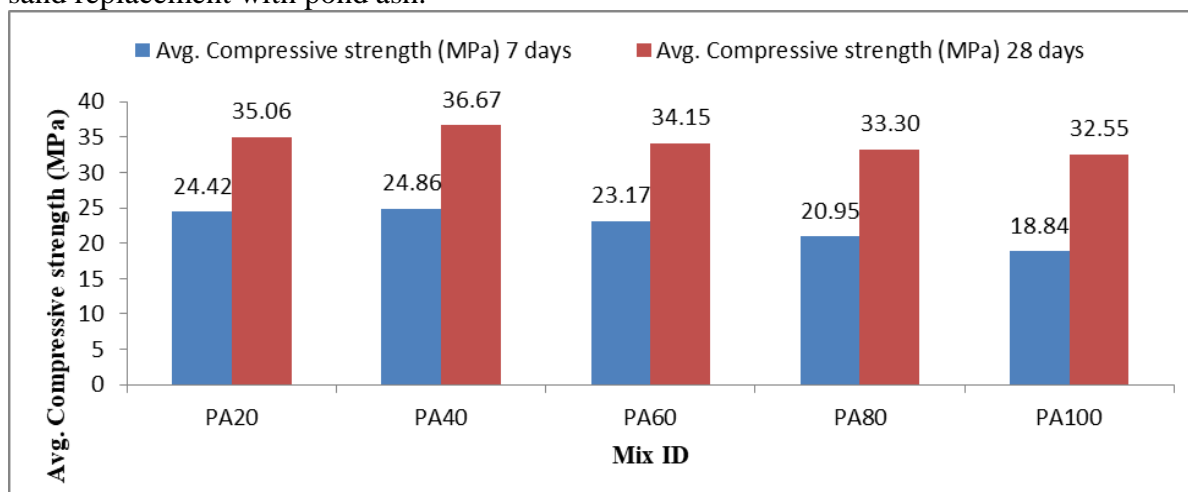


Figure3. Compressive Characteristics of Crushed Sand, Pond Ash, blended Geo Composite

At 28 days of age, the PA40 specimen containing 40% pond ash and a molarity of 12 had the highest compressive characteristics, averaging 36.67 MPa. 40% was the ideal pond ash proportion. The results of the experiment show that when the amount of pond ash climbs above 40%, compressive strength decreases.

4.3.2 Flexural Characteristics: Variations of Crushed Sand, Pond Ash Integrated Geo Composite Block

Flexural characteristics and variations concerning the percentage additions of pond ash were experimented. The results of the experiment indicated that a 40% replacement of crushed sand with pond ash showed higher flexural characteristics. Flexural characterizes the value of 3.54 MPa; 4.73 MPa was attained as the maximum value by the crushed sand replacement with pond ash.

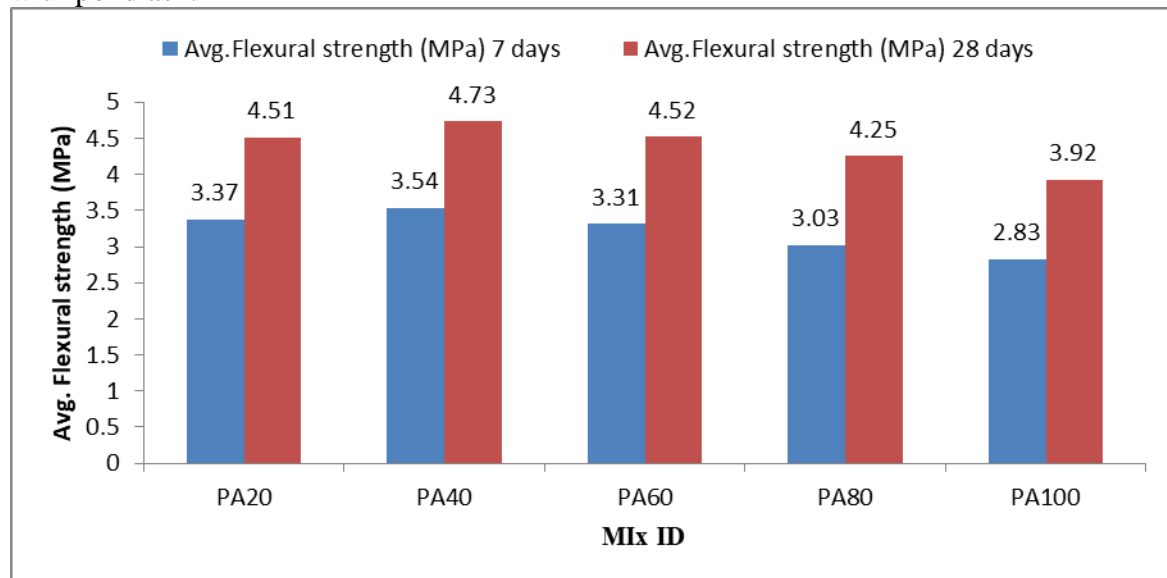


Figure 4. Flexural characteristics of crushed sand and Pond ash integrated Geo composite.

According to the test findings, the flexural characteristics of geopolymer composite at all ages are reduced when the proportion of pond ash with crushed sand is increased over 40%. The flexural strength changes for various ratios of pond ash to crushed sand are shown in Figure 4. The 40% pond ash with a molarity of 12 achieved the maximum flexural strength value of 4.73 MPa.

4.4.1. Compressive characteristics of pond ash and oyster shell ash integrated into geocomposite.

To assess the combined influence of pond ash and oyster shell ash on the compressive characteristics of geo composite, trial and error experimentation was done. The optimal proportioning of pond ash was first frozen, and then for this value, the optimal combinational proportioning of oyster shell ash was obtained. The compressive characteristics values of pond ash and oyster shell ash integrated geocomposites are shown in Figure 5.

Figure 5. Compressive characteristics of pond ash and oyster shell ash integrated geocomposite.

At 28 days of age, the PA40OSA40 blended specimen's maximum compressive characteristics was measured at 37.31 MPa. It was determined that 40% was the ideal amount of oyster shell ash to use as a partial substitution for crushed sand. Outcomes from experiments indicate that compressive characteristics decrease when oyster shell ash content rises above 40%.

4.4.2. Flexural characteristics of pond ash and oyster shell ash integrated geocomposite.

The flexural characteristics of pond ash and oyster shell ash integrated geocomposite were determined. Flexural characteristics of variations of geocomposite for diverse crushed sand

replacement percentages of pond ash and oyster shell ash integrated geocomposites after are shown in Figure 6. At 7 and 28 days of age, the flexural strengths of different percentages of oyster shell ash range from 3.32 MPa to 3.63 MPa and 4.21 MPa to 4.76 MPa, respectively. A maximum flexural characteristics value of 4.76 MPa was attained for the specimen PA40OSA40, comprising 40% pond ash and 40% oyster shell ash, after 7 days of curing, and for samples at 28 days period of curing

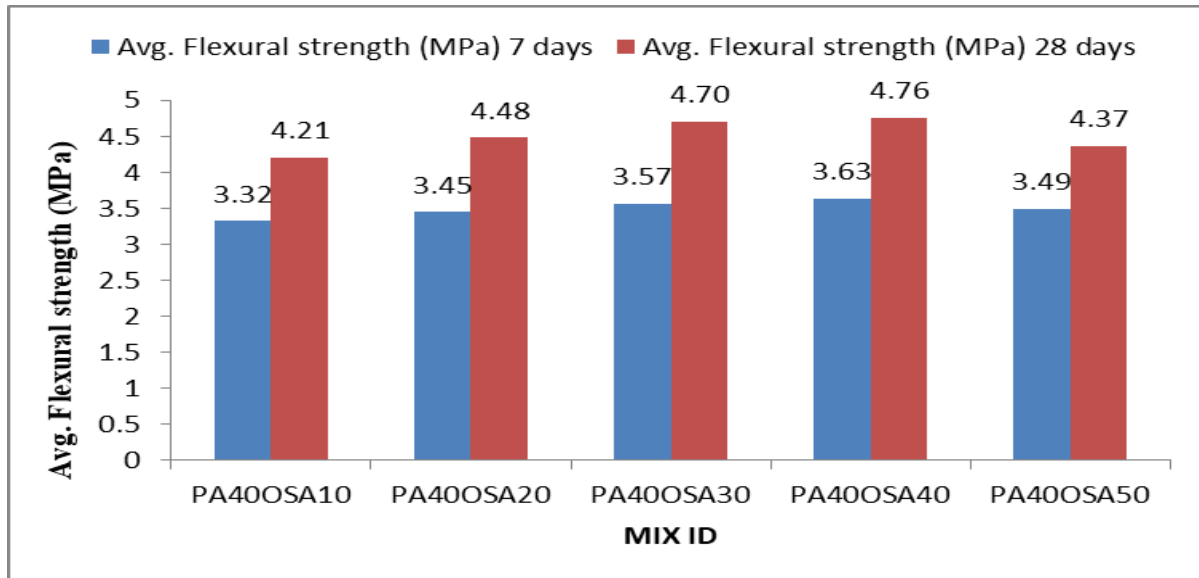


Figure 6. Flexural characteristics of pond ash and oyster shell ash integrated a geocomposite .

Outcome from experiments indicate that flexural characteristics of geopolymer composite at all ages is reduced decrease when oyster shell ash content rises above 40%. The differences in flexural characteristics for varying ratios of pond ash and oyster shell ash with crushed sand are revealed as figure 6. With PA40OSA40 blended proportions, the greatest flexural strength value of 4.64 MPa was achieved when 40% oyster shell ash was substituted for crushed sand.

4.5. Weight Loss of Pond Ash and Oyster Shell Ash Integrated Geo Composite Samples Utilizing H₂SO₄

Owing to the H₂SO₄ attack experimented on pond ash and oyster shell ash-integrated geocomposite block samples, weight loss was obtained for diverse periods of 30, 60, 90, and 120 days. Weight loss of fly ash-based geo composite (CS4), weight loss of PS40 sample, and optimal percentage of pond ash and oyster shell ash integrated geo composite block (PS40OSA40) samples due to sulphuric acid attack and the correlation of % weight loss of samples (H₂SO₄curing) are shown in Figure 7. An evaluation due to H₂SO₄curing was made for the blending ratios of CS4, PS40, and PS40OSA40.

Figure 7. % Weight loss of pond ash and oyster shell ash integrated into a geocomposite block (H₂SO₄ curing)

On evaluation, it was established that an escalation in weight reduction for PS40 and PS40OSA40 was observed in contrast to CS4 due to the poorer previous characteristics.

4.6. Probability of Corrosion in Crushed Sand Pond Ash and Oyster Shell Ash-Integrated Geocomposite .

The likelihood of corrosion in steel contained in CS4, PS40, and PS40OSA40 combinations was evaluated using a half-cell potential test. The half-cell potential values were used to determine the likelihood of corrosion pursuant to ASTM C-876 criteria. It is an indirect

method to assess the likelihood of corrosion. Figure 8 shows the possible half-cell values for the CS4, PS40, and PS40OSA40 combinations..

To evaluate the likelihood of corrosion in steel contained within CS4, PS40, and PS40OSA40 combinations, a half-cell probability assessment was performed. The half-cell potential values were used to evaluate the likelihood of corrosion in accordance with ASTM C-876 guidelines. The likelihood of corrosion is evaluated indirectly. Figure 8 shows the possibility of half-cell values for the PS40, CS4, and PS40OSA40 combinations.

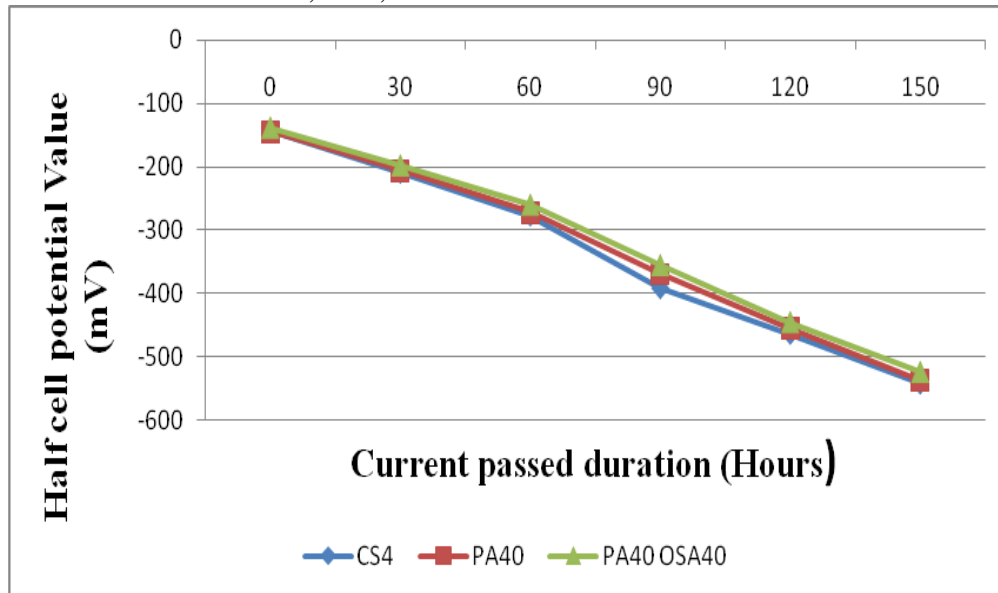


Figure 8. Probability of Corrosion in Crushed Sand, Pond Ash, and Oyster Shell Ash-Integrated Geocomposite.

5. Conclusion

1. The outcome of the investigations establishes that crushed sand geocomposite with an optimum molarity of 12 can be best suited with the elimination of the primary ingredient cement, a substantial diminution in CO₂ emanation, and universal warming with the required compressive characteristics and strengths for practice.
2. The outcomes of various tests on the geocomposite demonstrated that a 12 molarity ratio was sufficient to achieve the robustness needed for the M₃₀ grade.
3. The optimal substitution of crushed sand was found to be 40% pond ash.
4. The tests on mechanical properties revealed that a maximum of 40% oyster shell ash can be exploited as a substitute in part for crushed sand.
5. The weight loss assessment's findings showed that the proportion of weight reduction rose as time went on. The same blueprint was also pragmatic for the optimal proportion of pond ash blended geo composite (with 12 m) and oyster shell ash integrated geo composite (using 12m + 40 percent pond ash as a partial replacement for crushed sand).
6. According to the results of half-cell potential tests, the addition of geocomposite with 12m plus 40% pond ash as a partial replacement for crushed sand and 40% oyster shell ash as a fractional replacement for crushed sand reduced the likelihood of corrosion..

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