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DURABILITY OF CONCRETE USING FLY ASH AGGREGATE AS COARSE AGGREGATE AND M-SAND AS FINE AGGREGATE

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Abstract

The study aimed to found changes in the durability of concrete made with fly ash coarse aggregates and manufacturedsand. The fly ash coarse aggregates were made at 10:90, 15:85, 20:80, and 25:75 proportions of cement and fly ash using the cold bonded technique. The fly ash aggregates at the best proportion 15:85 were selected as a coarse aggregate by conducting tests like specific gravity, crushing value, impact value,and water absorption tests.The experimental research wasdone to assessthe durabilityproperties of M25 design mix concrete specimens made with these fly ash coarse aggregates and manufacturedsand available in nearby stone crushers were used. The specimens were preparedby replacing the crushed stone coarse aggregates at percentages of 0%,10%,20%,30%, and40% by volume with fly ash coarse aggregates and manufactured-sand used as a fine aggregate.All the cast concrete specimens, including conventional mix specimens after curing for 28 days in normal water, were soaked for 90 days in the chemical water solution made with 3% of H_2SO_4. Durability properties, like a loss in weight and compressivestrength, were found on the specimens. The results showed that at 30% replacement of fly ash aggregate gives better durability compared to conventional concrete made with crushed stone coarse aggregates.

Keywords: Fly ash coarse aggregates;Manufactured sand;Cold bonded technique;Loss in weight;loss in compressive strength.

1. INTRODUCTION

The concrete construction industry has been developing very rapidly in the world.It consumes alargequantity of natural/crushed stone aggregate (coarse aggregate) and river sand (fine aggregate) in concrete manufacturing. Due to depletion, non-availability, and environmental issues related to the natural/crushed stone coarse aggregates and river sand and environmental issuesrelated tothe disposal of industrial wastes such as fly ash, we have to think feasible alternatives.One such alternative is replacing natural/crushed stone coarse aggrega**tes** with fly ash coarse aggregates and river sand with manufacturedsand (M-sand).

Fly ash coarse aggregates

Fly ash in fine powder is formed by the combustion of pulverized coal from solid waste and coal, iron industry, thermal industry, and power plants.Fly ash hasa pozzolaniccharacter and is a substance containing aluminous (Al_2O_3) and siliceous (SiO_2) materials. Even though many areas people started using fly ash,there is still a considerable quantity to dispose of, so we have to plan to consume the remaining quantity. One such a plan of utilizing fly ash is converting it as fly ash coarse aggregates and using it as coarse aggregate in the concrete.The pelletization process was used toformation of fly ash coarse aggregates from fly ash.

Fly ashcoarse aggregates are manufactured by using different propositions of cement and fly ash by mixing with water, using the cold bonded technique. The fly ash coarse aggregates at the best proportion may be selected as a coarse aggregate by conducting tests, like specific gravity, crushing value, impact value, and water absorption tests.

In this study,the best proportion of fly ash coarse aggregates was selected, and the experimental study was carried out to assess the durability properties of M25 design mix concrete specimens by replacing the crushed stone coarse aggregates at proportions of 0%, 10%, 20%, 30% & 40% by volume. Furthermore, River sand (fine aggregate) is entirely replaced with manufacturedsand (M-sand). All the cast concrete specimens, including conventional mix specimens after curing for 28 days in normal water, were soaked for 90 days in the chemical water solution made with 3% of H_2SO_4. Acid attack testswere conducted on the specimens.

2. LITERATURE REVIEW

Job et al. (2020) studied the properties of cold-bonded aggregates prepared with varying proportions of quarry dust and fly-ash. They observed that cold-bonded aggregates made at 37.5% quarry dust and 62.5% fly-ash proportion possesses the best strength properties, and hence these aggregates considered for further study. Concrete specimens were prepared by replacing crushed stone coarse aggregates with 0%, 25%, 50%, 75%, and 100% of the coldbonded aggregates. Some specimens without elevated temperatures and some were exposed to 200°C, 400°C, and 600°C were considered for the study. The strength and durability properties of these specimens were studied. They concluded that 100% replacement of crushedstone coarse aggregates with cold-bonded coarse aggregates in concrete does not show a significant difference in strength. Hence 100% replacement of the crushed stonecoarse aggregates with cold-bonded coarse aggregates was recommended.

Gopiand Revathi (2019)studied the strength and durability properties of concrete of SelfCompacting Concrete (SCC) mix prepared with pre-saturated Light Expanded Clay Aggregate (LECA) and Fly Ash Aggregate (FAA). The fine aggregate was replaced in the concrete mixes at the proportions of 0%, 5%, 10%, 15%, 20%, and 25% by volume. Also, Self-Compacting Self Curing Concrete (SCSCC) mix prepared with the blend of LECA and FAA. After 3, 7, 28, 56, and 90 days of curing compressive strength tests, and after 28, 56, 90, and 180 days of curing,durability tests were conducted. Durability tests are Sulphate Resistance Test (5% magnesium sulphate solution) and Acid Resistance Test (3% hydrochloric acid solution). The SCC possesses better compressive strength and durability at 15% of LECA or FAA, and SCSCC at 15% of FAA and 5% LECA.

Patel et al. (2019) studied the durability and microstructural properties of lightweight concrete made by way of replacing natural stone fine aggregate with fly ash cenosphere (FAC) and coarse aggregate with sintered fly ash aggregate (SFA) at proportions of 0%, 50%, 75%, and 100%. Tests like compressive strength, sulphate, acid, and chloride attack resistance of concrete, Scanning electron microscopy (SEM), and X-ray diffraction (XRD) analyses were carried. Results showed that appreciable enhancement in the strength and durability properties of concrete made at 50% FAC and 75% SFA.

Supriya et al. (2019) prepared the concrete mix by replacing the cement at 0%, 10%, 20%, 30%, and 40% with fly ash, At each proportion specimens were prepared with manufactured sand as fine aggregate, and fly ash coarse aggregate (made with 10% cement and 90% fly ash) as coarse aggregate. Fly ash aggregates are prepared by polymerization process using a cold bond technique where fly ash is mixed with alkaline activators 14 M NaOH and Na_2SiO_3. 30% replacement of fly ash showed better results than conventional concrete.

Bright and Muthukannan (2018) studied the strength and durability properties of two concrete mixes, one is Natural Aggregate Concrete (NAC) made with Natural Aggregate (NA),and the other one is Clay Aggregate Concrete (CAC) made with Expanded Flyash Clay Aggregate (EFCA). Strength tests (Compressive, Splitting tensile, and flexural strength) and durability tests (rapid chloride penetration test on the specimens exposed to 3% NaCl solution on one side and 0.3N NaOH solution on another side) were conducted on the specimens made with the two concrete mixes.The CAC showed positive results on both strength and durability properties. Hence, they recommended CAC as an alternative for NAC. **Srinivasan et al. (2016)** prepared artificial aggregates by mixing fly ash, rice husk ash, and iron ore dust with

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cement.Then, the concrete specimens were made with artificial aggregates. The mechanical (compressive strength) and durability (loss in compressive strength after curing with 5% NaCl solution) properties were studied on the specimens. The concrete specimens showed positive results on both strength and durability properties.

3. METHODOLOGY

1. The materials like cement, M-Sand, crushed stone coarse aggregates, fly ash coarse aggregates, the grade of concrete, and water-cement ratio are adopted, and their characteristics values have been thoroughly scrutinized
2. The design mix is exhausted with the required w/c ratio for the M25 grade of concrete.
3. Fly ash aggregates were made at 10:90, 15:85, 20:80, and 25:75 proportions of cement and fly ash, for these aggregates specific gravity,impact value, and crushing value are determined. The best proportion (15:85) of fly ash aggregates ischosen.
4. The concrete mix was prepared by partially replacingcrushed stone coarse aggregates with fly ash coarse aggregatesatvarious proportionsof 0%, 10%, 20%, 30%, & 40%.
5. The cubes were cast and tested after curing for 28 days in normal water, were soaked for 90 days in the chemical water solution made with 3% of H_2SO_4, and found the optimum proportion based on loss in weight and compressive strength.

4. MATERIALS AND METHODS

4.1 Cement

Ordinary Portland cement of 53grade (UltraTech brand) satisfies the requirement as per IS 12269:2013was used in the present investigation. The physical properties of cement are conducted as per IS 4031. The physical properties are tabulated in Table1.

Table 1: Physical properties of the cement

S.No.	Property	Test value	Standard value (IS 12269: 2013)	Method of a test, Ref. to
1	Specific gravity	3.13	---	IS 4031 (Part 11): 1988
2	Fineness, m^2/kg	370	Min. 225	IS 4031 (Part 2): 1999
3	Soundness, mm (By Le-Chatelier method)	6	Max. 10	IS 4031 (Part 3): 1988
4	method) Initial setting time, min	42	Min. 30	IS 4031 (Part 5): 1988
	Final setting time, min	350	Max. 600	
5	Compressive strength, MPa (After 28 days curing)	53	Min. 53	IS 4031 (Part 6): 1988

4.2 Manufactured sand (M-sand)

Thelocally available Manufactured sand (M-sand) of size less than 4.75mmisobtained from the nearby stone crusher and utilized in the present investigation. The various physical properties of the M-sand were conductedas per IS 2386: 1963,and the test results were shown in Table 2.

Table 2: Physical properties of M-Sand

S.No.	Property	Test value	Standard value (IS 383: 2016)	Method of a test, Ref. to
1	Specific gravity	2.58	Max. 3.2	IS: 2386 (Part III) – 1963
2	Water absorption, %	2.2	Max. 5	IS: 2386 (Part III) – 1963
3	Bulk density, kg/m^3	1659	---	IS: 2386 (Part III) – 1963
4	Grading Zone	Zone II	Zone I to IV	IS: 2386 (Part I) – 1963

4.3 Coarse Aggregate

Locally available crushed stone coarse aggregates of maximum size 20 mmareobtained from the nearby stone crusher and tested for their properties as per IS: 2386-1963,and the test results are shown in Table 3.

Table 3:Physical properties ofcrushed stonecoarse aggregates

S.No.	Property	Test value	Standard value (IS 383: 2016)	Method of a test, Ref. to
1	Specific gravity	2.66	Max. 3.2	IS 2386 (Part III): 1963
2	Water absorption, %	0.25	Max. 5	IS 2386 (Part III): 1963
3	Unit weight, kg/m^3	1593	---	IS 2386 (Part III): 1963

4.4 Fly ash coarse aggregates

Fly ash aggregates are produced by mixing of fly ash and cement with water,using the cold bonded technique. The cement and fly ash of various propositions (10:90, 15:85, 20:80, and 25:75) are tried with suitable water to get the fly ash pelletized aggregates, after 28 days of curing in normal water. Testswere conducted like specific gravity, crushing value, impact value, and water absorption on these aggregate. The optimum proportion of 15:85 was considered for further study based on the crushing and impact values which are nearer to the crushed stone coarse aggregates, and it also helpsto use maximum flyash with minimum cement quantity. The results at various proportions are publicized in Table 4.

Table 4: Physical properties of fly ash aggregates

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S. No.	Property	crushed stone coarse aggregates	Fly ash coarse aggregates at the ratio of cement: fly ash			
			10:90	15:85	20:80	25:75
1	Specific gravity	2.66	1.43	1.52	1.61	1.75
2	Crushing value (%)	25.72	27.26	25.38	24.78	25.12
3	Impact value (%)	23.63	24.21	23.39	21.24	20.16
4	Water absorption (%)	0.25	11.34	9.67	8.83	7.69

4.5 Durability of hardened concrete

4.5.1 Acid attack:

Acid attack is one of the causes of concrete deterioration. It happens when concrete comes in contact with sulphuric acid (H_2SO_4). Acid attack con concrete by dissolving both hydrated and un-hydrated cement compounds as well as calcareous aggregates. Sulphuric acid attack causes a wide formation of gypsum on the surfaces of the concrete.Itcauses disintegration and mechanical stresses, which leads to spalling and exposure of the new surfaceto the concrete.

Generally, the chemical changes of the cement matrix are restricted to the regions on the surfaces of concrete because of less penetration of the sulfuric acid in concrete.However, in some cases, it is observed that scaling and softening of the concrete occurs due to the early decomposition of calcium hydroxide and the subsequent formation of a large amount of gypsum. In this experimental investigation, the specimens are cured for 90 days in 3% of the H_2SO_4 chemical solution and then tested.

4.5.2 Loss of weight test:

The cube specimens were used for chloride resistance test by following IS 456-2000. The specimens were soaked in normal water for 28 days. After the curing period, the specimens were weighed (W_1) and soaked for 90 days in the chemical water solution made with 3% of H_2SO_4. After 90 days, the specimens were taken outside and once again weighed (W_2). Then, the percentage of losses in weight of specimens was calculated.

Percentage (%) of loss = $(W_1 – W_2)/W_1$ x100

Where,

W1 - Weight of cube specimen before soaking in the chemical water solution.

W2 - Weight of cube specimen after soaking in the chemical water solution.

4.5.3 Compressive strength test:

The compressive strength test was conducted on cube specimens, after 90 days soaking in the chemical water solution made with 3% of H_2SO_4, using a compression testing machine of capacity 2000 kN following IS 516:1959 specifications.

5. RESULTS AND DISCUSSIONS

5.1 Loss in weight:

The concrete specimens were made by replacing crushed stonecoarse aggregates with fly ash coarse aggregates at proportions of 0%, 10%, 20%, 30%, and 40%. After curing for 28 days in normal water, all these specimens were soaked for 90 days in the chemical water solution made with 3% of H_2SO_4,and tests were conducted. Results were tabulated in Table 5 and the corresponding graphical representation shown in Figure 1.

Table 5: Loss in weight of concrete made at various propositions offly ash coarse aggregates after 90 days of curing in the chemical water solution.

S.No.	% of fly ash coarse aggregates	Weight of the specimen before curing in chemical water solution (W_1) (kg)	Weight of the specimen after curing in chemical water solution (W_2) (kg)	% of loss in weight of the specimen
1	0%	8.312	8.073	2.88
2	10%	8.354	8.126	2.73
3	20%	7.995	7.780	2.69
4	**30%**	**7.636**	**7.437**	**2.61**
5	40%	7.277	7.061	2.97
6	50%	6.918	6.674	3.52

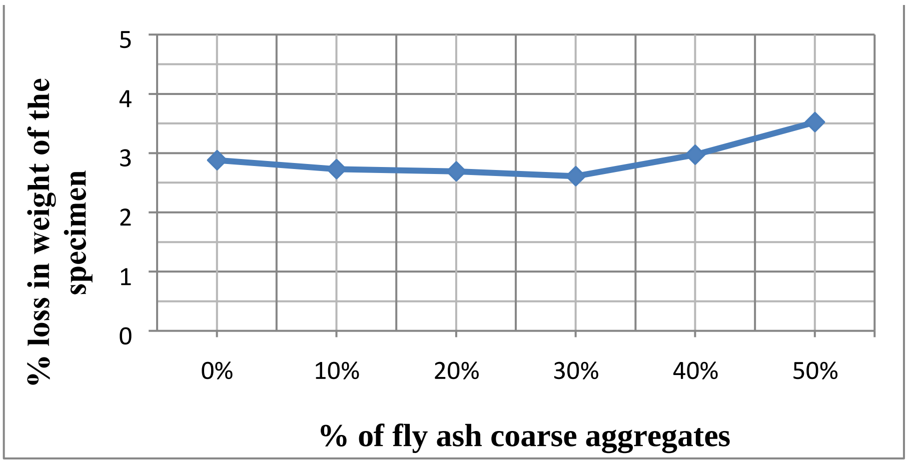

Figure 1: Loss in weight of concrete made at various propositions of fly ash coarse aggregates after 90 days of curing in the chemical water solution.

5.2 Compressive strength of concrete:

The test carried out on concrete by using fly ash coarse aggregates. The size of cubes 150mm x 150mm x150mm dimensions are selected, and the concrete specimens were prepared using fly ash aggregates by replacing with crushed stone coarse aggregates of propositions 0%, 10%,20%,30%, and 40% and using M-sand as fine aggregate for M25 grade of concrete.After curing for 28 days in normal water, all these specimens were soaked for 90 days in the chemical water solution made with 3% of H_2SO_4, and tests were conducted.The results were tabulated in Table 6 and the corresponding graphical representation shown in Figure 2.

Table 6: Loss in compressive strength of concrete made at various propositions of fly ash aggregate after 90 days of curing in the chemical water solution.

S.No.	Type of mix	Compressive strength before soaking in the chemical water solution (N/mm^2)	Compressive strength after soaking in the chemical water solution (N/mm^2)	% of loss in compressive strength
1	0%	31.82	28.915	9.13
2	10%	32.62	29.811	8.61
3	20%	33.21	30.414	8.42
4	**30%**	**35.14**	**32.287**	**8.12**
5	40%	32.16	29.314	8.85
6	50%	29.83	26.746	10.34

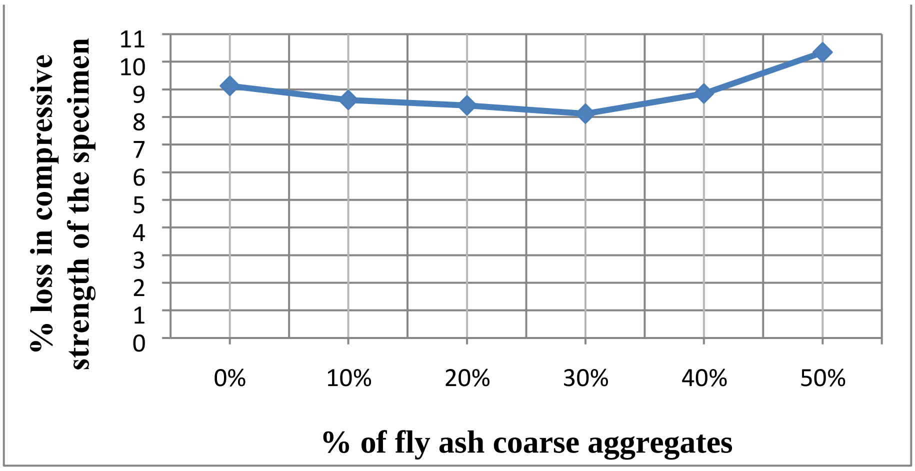

Figure 2: Loss in compressive strength of concrete made at various propositions of fly ash aggregate after 90 days of curing in the chemical water solution.

6. CONCLUSIONS

Based onthe experimentalresearchand analysis,the following conclusions were drawn.

1. Fly ash aggregates were made at 10:90, 15:85, 20:80, and 25:75 proportions of cement and fly ash with suitable waterand cured for 28 days in normal water. In this process,the cold-bonded technique was used. The optimum proportion of 15:85 was considered as the fly ash coarse aggregates for the study based on the crushing, impact, and water absorption values.
2. The strength properties of M25 design mix concrete specimens were evaluated by replacing the crushed stone coarse aggregates at proportions of 0%, 10%, 20%, 30%, 40%, and 50% by volume with fly ash coarse aggregates. Furthermore, river sand (fine aggregate) is entirely replaced with manufactured-sand (M-sand).
3. The results showed that at 30 % replacement of fly ash coarse aggregates gives better durability compared to conventional concrete.At this 30% replacement of fly ash coarse aggregates found minimum loss inweight and compressive strength. The weightloss of the specimen is 2.61%, whereas conventional concrete is 2.88%,which means 10.34% better weight. The loss in compressive strength is 8.12%, whereas conventional concrete is 9.13%,which means 12.44% better compressive strength.

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