EXPERIMENTALSTUDYON COMPOSITE CONCRETEUSING FLY ASH AGGREGATEANDM-SAND

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Abstract

The use of wastes such as fly ash is varied in concrete to achievebetter strength,and disposal of the waste can be largely reduced. Fly ash is mainly used for replacing cementduringthe preparation of concrete.However, in this study, fly ash aggregates prepared with fly ash and cement using a cold bonded technique was used. Fly ash aggregates were made at 10:90, 15:85, 20:80, and 25:75 proportions of cement and fly ash. 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 wasdoneto assessthe strength properties of M25 design mix concrete specimensmade with these fly ash aggregates. The specimens were preparedby replacing the natural stone coarse aggregates at percentages of 0%,10%,20%,30%, and40% by volume, and also river sand (fine aggregate) is entirely replaced with manufactured-sand (M-sand).Mechanical properties, like compressive,splittingtensile, and flexural strength tests were conducted on the specimens after 28 days of curing. The results showed that at 30% replacement of fly ash aggregate gives better strengths when compared to conventional concrete made with natural stone coarse aggregates.

Keywords: Fly ash Aggregates; M-sand;Cold bonded technique;Compressive strength;Splitting tensile strength;Flexural strength.

1. INTRODUCTION

Concrete is the essential material used in the construction industry fora longtime in various construction fields such as buildings, bridges, pavements, dams, marine, sanitary structures, and many others. Concrete is an integrated material made up of cement, fine, and coarse aggregate bonded together with water that hardens over some time.Generally, usual gravel and crushed stones are considered as coarse aggregates. Coarse aggregate occupies alarge (one-third) volume of concrete and also possessesthe strength to the hardened concrete.

Crushed stone aggregates, extraction are of increasing concern in many parts of the country. The impact includes loss of forest, noise, dust, blasting vibrations, and pollution hazard unplanned removal of rocks that may lead to landslides of the weak and steep hill slope. So, the coarse aggregates are replaced with industrial wastes gaining importance as additives because they increase strength, decrease density, and, most importantly, decrease environmental impacts. Fly ash aggregates are one such industrial wastes using as a coarse aggregate.

Fly ash aggregate

Fly ash is a pozzolanic activity, a substance containing aluminous (Al_2O_3) and siliceous (SiO_2) materials. Fly ash is produced due to solid waste and coal, iron industry, thermal industry, and power plants. Worldwide (30-35%) fly ash as a waste product from a power plant. In India fly ash production is 131 MT/yearand is expected to increase 250- 300MT/year, so it creates a great disservice to the environment. Fly ash is a resource material useful for various construction applications by efficient replacement of cement and aggregate on concrete because due to the spherical shape of fly ash particle, it can increase the workability of cement while reducing water demand. Hence fly ash is used in making lightweight aggregates; these aggregates are known as fly ash aggregates. The process of formation of fly ash aggregates from fly ash throughpelletization.

Fly ash aggregates are manufactured by using different propositions of cement and fly ash by mixing with water, using the cold bonded technique. The fly ash 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 aggregates were selected, and the experimental investigation was carried out to evaluate the strength properties of M25 design mix concrete specimens by replacing the natural stone coarse aggregates at proportions of 0%, 10%, 20%, 30% & 40% by volume. Furthermore, River sand (fine aggregate) is entirely replaced with manufactured-sand (M-sand). Mechanical properties, likecompressive,splitting tensile,and flexural strength tests were conducted on the specimens after 28 days of curing.

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 hencethese aggregates considered for further study. Concrete specimens were prepared by replacing natural stone coarse aggregates with 0%, 25%, 50%, 75%, and 100% of the cold-bonded 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 normal coarse aggregates with cold-bonded coarse aggregates in concrete does not show a significant difference in strength. Hence 100% replacement of the normal aggregates with cold-bonded coarse aggregates was recommended.

Ajmal and Palanisamy (2019)study,different mixtures of geo-polymers were made using different molarities (8, 10, 12, 14, and16) of NaOH solution and at each molarity varying alkaline solution to fly ash at ratios of 0.3, 0.35, and 0.4. These mixtures were cast, cured, and pulverized as fly ash artificial coarse aggregates (FACA).FACA at 8 molar NaOH solution and alkaline solution to fly ash ratio of 0.4 gives improved properties and is used for further study. Using the FACA,fly ash artificial coarse aggregate concrete (FACACRETE) specimenswere prepared for M20, M25, and M30 mixes.Tests were conducted on these specimens and compared with nominal concrete specimens. Results show that higher compressive strength, splitting tensile strength, flexural strength, toughness ratio, and residual strength of concrete compared to the normal concrete.

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) analyseswere carried.Results showed that appreciable enhancement in the strength and durability properties of concrete made at 50% FAC and 75% SFA.

Satpathy et al. (2019)they prepared lightweight concrete (LWC) specimens by replacingnatural fine aggregate (NFA) by fly ash cenosphere (FAC) and natural stone coarse aggregate (NCA) by sintered fly ash aggregate (SFA)at various proportions of 0%, 50%, 75% and 100% each.Workability, compressivestrength, splitting tensilestrength, flexuralstrength, bond strength, water absorption, pulse velocity, rebound number,and some moretests were conducted on the specimens after 28 days of curing.The LWC concrete prepared with 50% FAC and 75% SFA meets the requirement of the M25grade (desired) concrete as per IS 456:2000. Moreover, the LWC produced with 50% FAC and 100%SFA and 75% FAC and 50% SFA also meets the requirement of the M20 grade concrete.

Kailash and Rashmi (2018) studied the effect on properties of micro concrete prepared by replacing natural stone coarse aggregates with sintered fly ash lightweight coarse aggregates at proportions of 0, 50, 60, 70, and 100%. Compressive, flexure, and bond strengths, drying shrinkage, and shrinkage tests were conducted on the micro concrete. The test results were compared with normal concrete.The results were satisfactory and comparable with the strength of normal micro concrete.

Manu and Dinakar (2017)they conducted experiments on concrete specimens prepared at0.25, 0.35, 0.45, 0.55, 0.65, and 0.75 water-cement (w/c) ratios, at each w/c ratio natural coarse aggregates are replaced with three sizes of sintered fly ash aggregates (2–4 mm, 4–8 mm, and 8–12 mm fractions).Compressive strength, splitting tensile strength, andsurface resistivity tests were conducted on these specimens.Based on the testresults, theyproposed a new mix design methodology that hasthe capability of producing compressive strength up to 70 MPa without adding any mineral additives.The properties of the developed concrete mixes are satisfactory and suitable for structural applications as perASTM C 330 requirements.

3. METHODOLOGY

1. The materials like cement, M-Sand, natural 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.
4. The best proportion (15:85) of fly ash aggregates ischosen.
5. The concrete mix was prepared by partially replacing natural stone coarse aggregates with fly ash coarse aggregatesatvarious proportionsof 0%, 10%, 20%, 30%, & 40%.
6. The cubes,cylinders, and beamswere cast and tested for these proportions for 28 days and found the optimum proportion based on compressivestrength, splitting tensilestrength, and flexural strength test results.

4. MATERIALS AND METHODS

4.1 Cement

Cement is a bonding material,it reacts with fine aggregate, and coarse aggregate with the addition of water gives concrete. 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	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)

It is also known as artificial sand;it is a type of sand produced from the crushing of granite rocks.Thelocally available M-Sandof size less than 4.75mmis 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

The coarse aggregates are granite origin, and it is free from clayey matter, silt, and organic impurities. The maximum size of 20 mm is used as a coarse aggregate in concrete. Locally available coarse aggregate is tested for their properties as per IS: 2386-1963,and the test results are shown in Table 3.

Table 3:Physical properties ofcoarse aggregate

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. The cement and fly ash of various propositions (10:90, 15:85, 20:80, and25:75) 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 absorptionon these aggregate. The optimum proportion of 15:85 was considered for further study based on the crushingand impact values which are nearer to the normal 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

S. No.	Property	Normal coarse aggregate	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. Tests on hardened concrete

4.5.1 Preparation of mix:

Fly ash aggregate concrete mix were prepared by replacing the regularstone coarse aggregateswith the fly ash coarse aggregatesat propositionsof 0%, 10%,20%,30%, and 40% and alsoentirely replacing natural fine aggregate (river sand) with M-sand for M25 design mix concrete.

4.5.2 Compressive strength test:

The test specimens were made with the mix by filling and compacting at approximate layers of 50mm inthe cube of size 150mm x 150mm x150mm. The cube specimens were cured for 28 days and tested,and the average of three specimens was considered as the final value for compressive strength. Preparation and testing of concrete were donein accordance withIS 516:1959 specifications.

4.5.3 Splitting tensile strength test:

The test specimens were made with the mix by filling and compacting at approximate layers of 50 mm inthe cylinder of size 150mm in diameter and 300 mm long. The cylinder specimens were cured for 28 days and tested,and the average of three specimens was considered as the final value for splitting tensile strength. Preparation and testing of concrete were done in accordance withIS 5816:1999specifications.

4.5.4 Flexural strengthtest:

The test specimens were made with the mix by filling and compacting at approximate layers of 50 mm inthe standard size of the beam 150mm x 150mm x 700mm. The beam specimens were cured for 28 days and tested,and the average of three specimens was considered as the final value for flexural strength. Preparation and testing of concrete were done in accordance withIS 516:1959 specifications.

5. RESULTS AND DISCUSSIONS

5.1 Compressive strength: The compressive strength at various % of fly ash coarse aggregateswereobtained and compared with the conventional concrete. The results are revealed in tabular form in Table 5and pictorial form in Figure 1.

It is evident from the results that with the increasing fly ash coarse aggregates, the compressive strength also increased, and the optimum value obtained at 30% of replacement.

Table 5: Compressive strength of concrete for various % of fly ash coarse aggregate

S. No.	% fly ash coarse aggregate	Compressive strength for 28 days (N/mm^2)
1	0	31.82
2	10	32.62
3	20	33.21
4	30	**35.14**
5	40	32.16
6	50	29.83

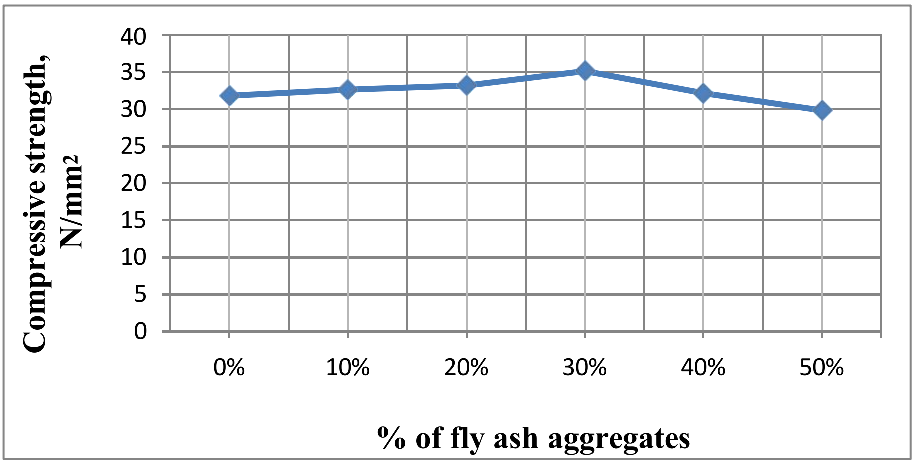

Figure 1: Compressive strength of concrete for various % of fly ash coarse aggregates

5.2 Splitting tensile strength: The splitting tensile strength at various % of fly ash coarse aggregates wasobtained and compared with conventional concrete. The results are revealed in tabular form in Table 6 and pictorial form in Figure 2.

It is evident from the results that with the increasing fly ash coarse aggregates, the splitting tensile strength also increased, and the optimum value was obtained at 30% of replacement.

Table 6: Splitting tensile strength of concrete for various % of fly ash coarse aggregate

S. No.	% fly ash coarse aggregate	Splitting tensilestrength for 28 days (N/mm^2)
1	0	3.12
2	10	3.56
3	20	3.71
4	30	**3.93**
5	40	3.19
6	50	2.74

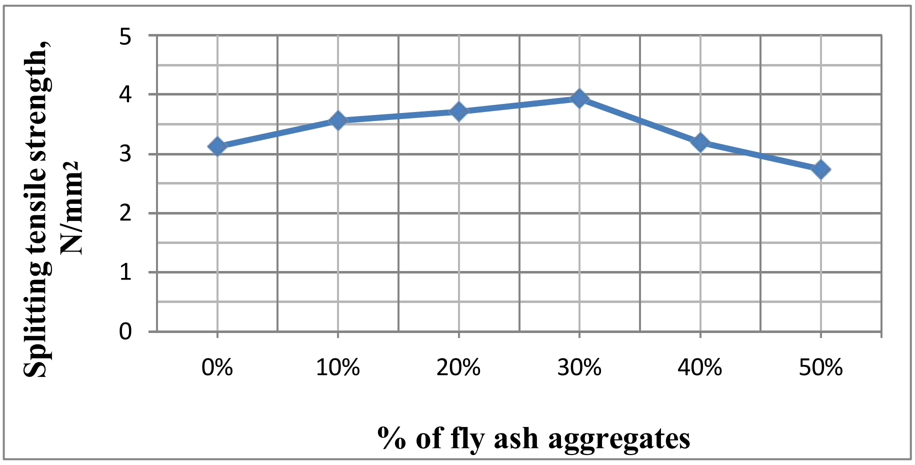

Figure2: Splitting tensile strength of concrete for various % of fly ash coarse aggregate

5.3 Flexural strength of concrete:

The flexural strength at various % of fly ash coarse aggregate wasobtained and compared with conventional concrete (0% fly ash coarse aggregate). The results are publicized in tabular form in Table 7 and pictorial form in Figure 3.

It is evident from the results that with the increasing fly ash coarse aggregates, the flexural strength also increased, and the optimum value was obtained at 30% of replacement.

Table 7: Flexural strength of concrete for various % of fly ash coarse aggregates

S. No.	% fly ash coarse aggregate	Flexuralstrength for 28 days (N/mm^2)
1	0	4.61
2	10	4.95
3	20	5.03
4	30	**5.21**
5	40	4.69
6	50	4.21

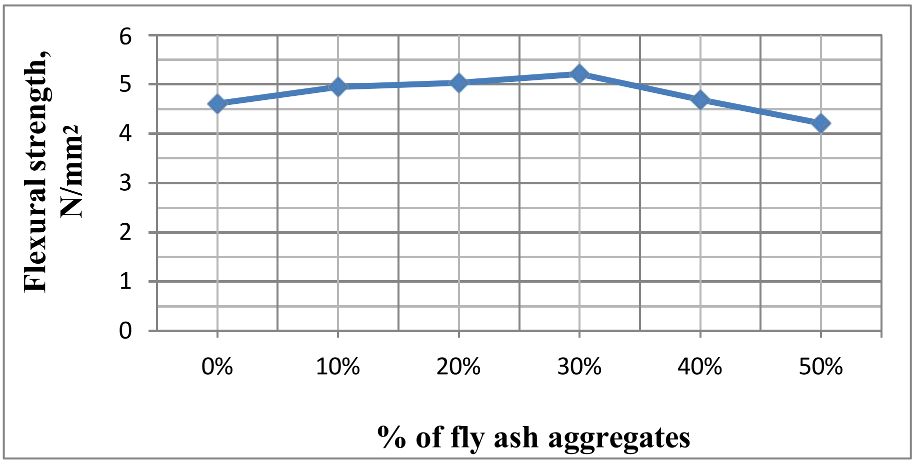

Figure 3: Flexural strength of concrete for various % of fly ash coarse aggregates

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 ashwith 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 regular stone coarse aggregates at proportions of 0%, 10%, 20%, 30%, 40%, and50% by volumewith fly ash 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 aggregates gives better strengths compared to conventional concrete.The compressive strength enhancedfrom31.82N/mm^{2}to 35.14N/mm^2 (10.43%), splitting tensile strength enhancedfrom3.12N/mm^{2}to 3.93 N/mm^2 (25.96%), andflexural strength enhancedfrom4.61N/mm^{2}to 5.21 N/mm^2 (13.05%).

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