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Partial Replacement of Cement with Fly Ash and Silica Fume for Sustainable Construction

Dr.S.Sundararaman[1], S.Azhagarsamy[2]

[1]Professor, [2]Assistant Professor, Department of Civil Engineering
Mailam Engineering College, Mailam, Villupuram District, Tamil Nadu 604 304
hodcivil@mailamengg.com[1], azhagarsamysekar@gmail.com[2]

Abstract -*The concept of partial replacement of cement which is capable for sustainable development is characterized by application of industrial wastes to reduce consumption of natural resources and energy and pollution of the environment. Presently large amounts of fly ash are generated in thermal industries with an important impact on environment and humans. This research work describes the feasibility of using the thermal industry waste in concrete production as partial replacement of cement. Fly ash and silica fume can be used as filler and helps to reduce the total voids content in concrete. The cement has been replaced by fly ash accordingly in the range of 0%, 25%, 30%, 35%, 40%, 45%, 50%, 55% and 60% by weight of cement and 10% of silica fume in common for M-30 mix. Concrete mixtures produced, tested and compared in terms of compressive and split tensile strength with the conventional concrete for 3, 7, 28 days. It is found that, 50% of fly ash and 10% of silica fume can be replaced and strength obtained is comparable to the conventional concrete.*

Key Words: Green concrete, Compressive Strength, split tensile strength, fly ash, silica fume.

1. INTRODUCTION

Green concrete is a concept of thinking environment into concrete considering every aspect from raw materials manufacture over mixture design to structural design, construction, and service life [1, 4]. Green concrete is very often also cheap to produce, because, for example, waste products are used as a partial substitute for cement, charges for the disposal of waste are avoided, energy consumption in production is lower, and durability is greater [3, 4]. In India there is an excessive production of fly ash as it is used in the production of electricity in nuclear power plants. Silica fume is an industrial waste containing heavy metals in its constitutes. By judicious use of available materials for concrete making and their proportioning, concrete mixes are produced to have the desired properties in the fresh and hardened states, as the situation demands. Waste can be used to produce new products or can be used as admixtures so that natural sources are used more efficiency and the environment is protected from waste deposits [5].To avoid the pollution and reuse the waste material, the present study is carried out. As the properties are as good as the cement, the Class F fly ash (coal fly ash) and silica fume is used as fine partial replacement in the cement concrete [7].

2. MATERIALS AND EXPERIMENTAL METHODOLOGY

2.1 Cement

The Ordinary Portland cement of 53-grade was used in this study conforming to IS: 12269-1987 [15]. The specific gravity of cement is 3.15. The initial and final setting times were found as 35 minutes and 178 minutes respectively. Standard consistency of cement was 31%.

2.2Fine aggregates

The river sand is used as fine aggregate conforming to the requirements of IS: 383-1970 [14], having specific gravity of 2.62 and fineness modulus of 2.86 has been used as fine aggregate for this study.

2.3Coarse Aggregate

Coarse aggregate obtained from local quarry units has been used for this study, conforming to IS: 383-1970 [14] is used. Maximum size of aggregate used is 20mm with specific gravity of 2.707.

2.4 Fly ash

Fly ash is a byproduct of the thermal power plants. Fly ash normally produced from burning anthracite or bituminous coal. Class F fly ash was used have a lower content of Cao and exhibit Pozzolonic properties [2]. Specific gravity of fly ash is 2.2 as per Specific gravity Test, IS: 2386 Part III, 1963,(ASTM C 618) [12].

Table -1: Chemical Composition of fly ash

Content	Cao	Sio2	Al2o3	Fe2o3	Mgo
Fly ash	2	60	30	4.0	1.0

2.5 Silica Fume

The specific gravity of silica fume is 2.2.It consists of 0.1 to 1 micron sized fine, smooth spherical glassy particles with fineness of $20m^2$/gmconforming to ASTM C1240-1999 standards.

Table -2: Physical properties of silica fume

Particle size	1µm
Bulk density	130 to 430 kg/m3
Bulk density	480 to 720 kg/m3
Specific gravity	2.2
Specific surface	15000 to 30000 m2/kg

2.6 Water

The water used for experiments was potable water conforming as per IS: 456-2000 [8].

3.0 EXPERIMENTAL PROCEDURE

M30 grade concrete mixes of different Fly ash levels (0% to 60% replacement of cement) and silica fume of 10% with w/c ratio of 0.45 were prepared. The mixes were designated in accordance with IS: 10262-2009 [10]. A total of 27 concrete cubes and 27 cylinders were casted for the different percentages of replacement of cement. The specimens were demoulded after 24 hours and curing was done for different age of testing. They were tested for their strength properties on 3rd, 7thand 28thday.

Table -3: Details of Mix Proportions of Concrete

Sl. No.	cement replacement %	cement	Coarse aggregate	Fine Aggregate	Cement replacement by fly ash	Cement replacement by silica fume
1	0%	479	1158.7	561.96	0	0
2	25%	347	1158.7	561.96	119.7	11.97
3	30%	320	1158.7	561.96	143.7	14.4
4	35%	293	1158.7	561.96	167.7	16.8
5	40%	266	1158.7	561.96	191.6	19.2
6	45%	238	1158.7	561.96	215.8	21.6
7	50%	211	1158.7	561.96	239.6	23.9
8	55%	184	1158.7	561.96	263.5	26.4
9	60%	157	1158.7	561.96	287.5	28.8

Table -4: Compressive strength of cubes on 3, 7 and 28 Days

% Replacement of fly ash	Compressive strength in N/mm2		
	3 Days	7 Days	28 Days
0	15.63	22.2	33.69
25	16.77	24.45	39.83
30	18.71	24.9	41.14
35	21.13	25.97	43.74
40	19.69	24.67	42.61
45	18.33	23.34	36.82
50	16.67	23.03	33.16
55	12.33	21.41	27.96
60	10.67	13.67	24.43

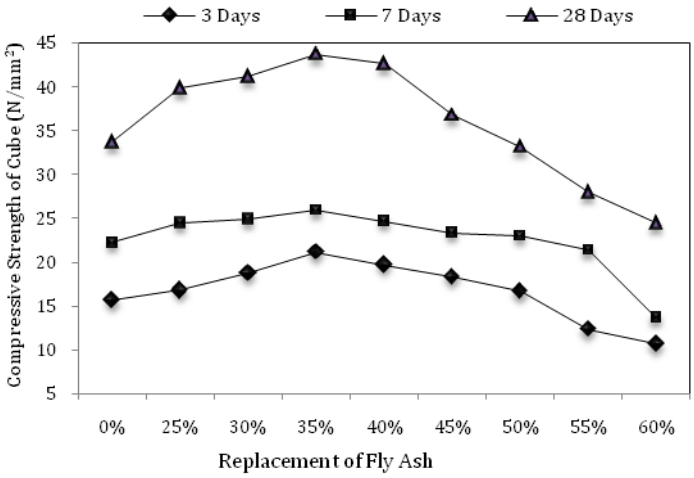

Chart -1: Compressive strength of cubes on 3, 7 and 28 Days

Table -5: Split Tensile Strength of cylinders on 3, 7 and 28 Days

% Replacement of fly ash	Split Tensile Strength in N/mm2		
	3 Days	7 Days	28 Days
0	7.7	15.38	19.75
25	6.48	13.05	17.19
30	5.4	10.69	14.5
35	5.05	10.5	13.03
40	4.5	9.87	13.05
45	4.2	8.91	9.87
50	3.7	8.28	9.23
55	3.1	7.64	8.28
60	2.1	6.68	6.68

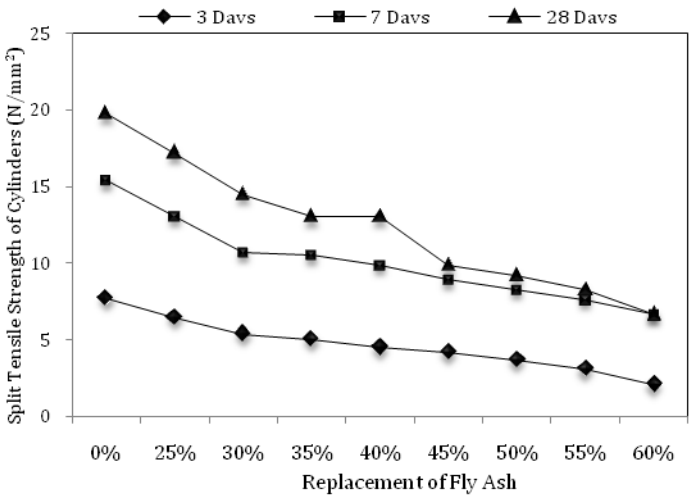

Chart -2: Comparison of Split Tensile Strength of Cylinders on 3, 7 and 28 Days

4.0 RESULTS AND DISCUSSION.

When the percentage of fly ash replaced to cement with varying percentage from 25% to 60% the following results were drawn.

1. With 25% of fly ash the compressive strength at the end of 3, 7 and 28 days 16.77, 24.45 and 39.83N/mm2 respectively.
2. A similar increase in the compressive strength was observed when the fly ash is increase till 35% (43.74N/mm2 at the end of 28 days).
3. The compressive strength at the end of 28 days decreases when the fly ash percentage is increased beyond 35%. However the compressive strength of M20 concrete at the end of 28 days for 50% replacement of fly ash is 33.16 N/mm2 as shown in Table -4.
4. The compressive strength showed a steep decrease when the fly ash percentage is increased beyond 50% as shown in Chart -1.
5. With 25% of fly ash the split tensile strength at the end of 3, 7 and 28 days 6.48, 13.05 and 17.19 N/mm2 respectively.
6. A similar increase in the split tensile strength was observed when the fly ash is increase till 35% (13.03 N/mm2 at the end of 28 days).
7. The split tensile strength at the end of 28 days decreases when the fly ash percentage is increased beyond 35%. However the split tensile strength of M20 concrete at the end of 28 days for 50% replacement of fly ash is 9.23 N/mm2 as shown in Table -5.
8. The split tensile strength showed a steep decrease when the fly ash percentage is increased beyond 50% as shown in Chart -2.

5.0 Conclusions:

Based on the experimental investigation the following conclusions were drawn on the strength characteristics.

1. Compressive and split tensile strength showed an increased value with the fly ash is replaced up to 50% at the end of 28 days.
2. Compressive and split tensile strength reduces when cement replaced by fly ash percentage is increased beyond 50% at the end of 28 days.
3. The results indicate that replacing cement with fly ashup to 50% is possible to be used in structural concrete[4].
4. From the above study, it is concluded that the fly ash and silica fume may be used as a replacement material for cement.
5. It can be concluded that replacement of cement with silica fume up to 10 % and 50% of fly ash replacement would render the concrete more strong and durable [8].

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BIOGRAPHIES

Dr.S.Sundararaman was born in 1979 in Pondicherry. He received his B.Tech degree in Civil Engineering from Pondicherry Engineering College, Pondicherry in 2001 under the Pondicherry University. He received his Master's degree in Environmental Engineering from P.E.S. College of Engineering, under the Visveswaraiah Technological University 2004. He received his Ph.D in Civil Engineering from Pondicherry Engineering College, under the Pondicherry University 2010. Presently he is Professor and Head of Civil Engineering Department with a total experience of 11 years in the field of Research, Industrial and Education. He has papers published in National Conference and International journals.

S.Azhagarsamy was born in 1987 in Pondicherry. He received his Bachelor of Engineering degree in Civil Engineering from V.R.S College of Engineering and Technology, Tamil Nadu in 2010 under the Anna University. He received his Master's degree in Advanced Construction Technology from Pondicherry Engineering College, Pondicherry in 2012 under the Pondicherry University. Presently he is Assistant Professor of Civil Engineering Department with a total experience of 4 years in Education. He has papers published in National Conference and International journals.