"EXPERIMENTAL STUDY ON PARTIAL REPLACEMENT OF CEMENT BY SEWAGE SLUDGE ASH AND GGBS IN CONCRETE"

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Abstract - *Concrete is the most widely used construction material in the civil engineering industry because of its high structural strength and stability. The concrete industry is looking for supplementary cementitious material or industrial by-products to reduce carbon dioxide emission which is harmful to the environment. Sewage sludge is an organic residue generated by municipalities following secondary and tertiary treatment of wastewater streams is used as a soil amendment and fertilizer to improve the yield of selected crops, as well as a fuel in co-combustion with other fuels or types of waste and is used as a replacement material for cement. Ground granulated blast furnace slag (GGBS) is the solid waste generated by the industry that is used as an alternative replacement material for cement. This paper deals with the effective utilization of waste material in concrete production as a partial replacement for Cement. The cement has been replaced by SSA in the range of 7.5%, 9%, 10.5%, 12%, 13.5%, and 15% by weight of cement, GGBS In the range of 10%, 20%, 30%, 40%, 50%, 60% percent by weight of cement. A workability test was carried out on fresh properties of concrete while compressive strength, split tensile strength, and flexural strength were carried out on hardened concrete. It is found that the partial replacement of cement with SSA and GGBS helped in improving the strength of the concrete substantially. Compressive strength test, flexural and split tensile strength test were carried out at 7 and 28 days curing period.*

Key Words: Sewage Sludge Ash (SSA), Ground Granulated Blast Furnace Slag (GGBS), Compressive Strength, Split Tensile Strength, Flexural Strength, and Workability.

1. INTRODUCTION

Concrete has been the major instrument for providing stable And reliable infrastructure since the days of Greek and roman civilizations. Concrete is the most world widely used construction material. With the increase in demand for concrete, more new methods and materials are being developed for the production of concrete. Concrete is a mixture of cement, water, and aggregates with or without chemical admixtures.

The most important part of concrete is cement. Use of cement alone as a binder material produces large heat of hydration. Since the production of this raw material produces a lot of CO_2 emission. The carbon dioxide emission from the cement raw material is very harmful to environmental changes. Nowadays many researchers have been carried out to reduce CO_2. The effective way of reducing CO_2 emissions from the cement industry is to use industrial by-products or use of supplementary cementing materials such as Sewage Sludge Ash (SSA), Ground Granulated Blast Furnace Slag (GGBS), Fly Ash (FA), Silica Fume (SF) and Metakaolin (MK).In this present experimental work, an attempt is made to replace cement with SSA GGBS to overcome these problems.

2. EXPERIMENTAL PROCEDURE

2.1 Materials and mixture proportions:

2.1.1 Ordinary Portland Cement [OPC]:

The cement used in the experiments was Ordinary Portland Cement of grade 53, which confirms IS12269:1987. The specific gravity of OPC cement is 3.15; the initial setting time is 30 minutes. The normal consistency of cement is 30% and the particle size range lies between 31um and 7.5um.

2.1.2 Fine Aggregate:

In concrete technology, the specific gravity of aggregate is used in the design calculation of concrete mixes. The standard specifications in IS:2386 part 3 of 1963 give various procedures to find out the specific gravity of different sizes of aggregates. In this study, tapi river sand was used. The specific gravity is 2.68.

2.1.3 Coarse Aggregate:

The ideal coarse aggregate should be clean cubical, angular, and 100% crushed aggregate with a minimum of flat and elongated particles, ACI 363R, 1992.The specific gravity of aggregate used in the design calculation of concrete mixes in the concrete technology. The standard specifications in IS:2386 part 3 of 1963 give various procedures to find out the specific gravity of different sizes of aggregates. In this study as a coarse aggregate, the medium well-graded aggregate was used. The specific gravity of this aggregate is 2.60.

2.1.4 Water:

The requirement of water confirmed to IS: 10262:2019 is found to be suitable for making concrete. The minimum water requirement for a medium well-graded aggregate of size 20mm-60% and 10mm-40% is 200Kg/m3 as confirmed by IS: 10262:2019 Table no 7 (clause 6.2.4).

2.1.5 Ground Granulated Blast Furnace Slag:

Ground granulated blast-furnace slag, GGBFS, is a by-product of iron in the blast furnace. It mainly consists of silicate and aluminosilicate of melted calcium that periodically needed to be removed from the blast furnace. Similar to fly ash, the chemical compositions of GGBFS depend on the raw materials used in the production of iron while the physical properties depend on the cooling process used to cool down the molten materials. It can be used in proportions of 5-30% of the cement content in the mix. Confirming IS 10262:2019, table no.9 (clause 6.2.6) For this experimental investigation 5-30%.

2.1.6 Sewage Sludge Ash:

Sewage sludge is an organic residue generated by municipalities following secondary and tertiary treatment of wastewater streams. It is used as a soil amendment and fertilizer to improve the yield of selected crops, as well as a fuel in co-combustion with other fuels or types of waste. Sewage sludge is disposed of by land spreading, burial in landfills, and incineration. It can be used in proportions of 5-30 of the cement content in the mix. Confirming to IS 10262: 2019. For this experimental investigation, 15% Sewage Sludge Ash was used.

3. TEST METHODS

3.1 Mixing Of Material:

Machine mixing was used for the mixing of material. First aggregate was added to the mixer, followed by 25% of total water to prevent cement from sticking to the blades or at the bottom of the drum. Initially, the specimen was cast using a 0.62 water-to-binder ratio. The aggregate of sizes 20mm and 10 were used as 60% and 40% while the Sewage Sludge Ash from 7.5 to 15% and GGBS from 5 to 30% by weight of cement at an interval of 2.5% and 10% were used as cementitious materials. In this experimental work, the behavior of mechanical properties of concrete such as compressive, split tensile, flexural, color, and workability was observed. A slump test is conducted for each mix to measure the workability of the concrete. Three cubes of 100X100X100mm, 3 cylinders of 150mm dia. and 300mm in height, and 3 beams of 100X100X500mm were cast for each mixes to measure the compressive strength, split tensile strength, and Flexural strength of concrete. A cylinder of 150mm dia. and 300 mm height are cast for each mixes to measure the modulus of elasticity of concrete. Totally 42 cubes, 42 cylinders, and 42 beams are cast. The cast specimens were kept at ambient temperature for 24 hours. After 24 hours they were molded and placed in water for curing.

3.2 Testing of Specimen:

All cube and cylinder specimens are tested for compression strength and tensile in Compression Testing Machine (CTM) and all the beams specimens are tested for flexural strength in a universal testing machine (UTM) shown in figure

Table No:-1 Mix Proportions of concrete

Sr. No	MATERIALS	QUANTITY
1	Cement(Kg/m^3)	390
2	Fine Aggregate(Kg/m^3)	717
3	Coarse Aggregate(Kg/m^3)	1163
4	Water(l/m^3)	164
5	Sewage Sludge Ash(Kg/m^3)	73
6	GGBS(Kg/m^3)	227
7	w/c ratio	0.42

Fig No. a) Flexural strength test
Fig No. b) Tensile strength test
Fig No. c) Comprehensive strength test
Fig No. d) Specimens After Testing

4. RESULT AND DISCUSSION:

4.1 Compressive Strength:

The compressive strength of concrete was determined at the age of 7 and 28 days as presented in graph Fig 2

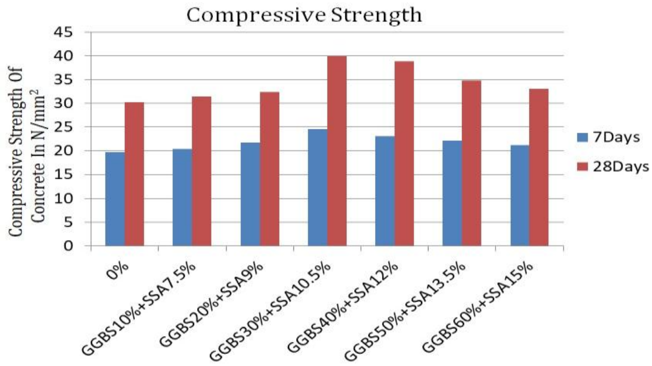

Fig.2 Compressive Strength at the age of 7 & 28 Days Curing

represents the compressive strength of concrete with partial replacement of cement by GGBS 0%, 10%, 20%, 30%, 40%, 50%, and 60% and SSA 7.5%, 9%, 10.5%, 12%, 13.5%, and 15%. During the curing period of 7 and 28 days, three specimens for each curing period were tested for their compressive strength [Fc] and their average compressive strength was shown in table 2.

Table No:-2 Average Compressive Strength (N/mm²)

Sr.No	GGBS %	Sewage Sludge Ash %	7Days	28Days
1	0%	0	19.70	30.21
2	10%	7.5	20.44	31.50
3	20%	9	21.77	32.42
4	30%	10.5	23.56	39.91
5	40%	12	23.10	38.85
6	50%	13.5	22.20	34.78
7	60%	15	21.23	33.00

From the table, it was identified that mix of 30% GGBS and 10.5% Sewage Sludge Ash has a higher compressive strength than other GGBS and Sewage Sludge Ash content. Table 2 shows The relationship between the compressive strength and Sewage Sludge Ash and GGBS volume fraction and aspect ratio. It demonstrates that the compressive strength increases with increasing Sewage Sludge Ash and GGBS content. However, it shows a relatively lower rate of increase. Test results show the compressive strength varied from 19.70 to 24.56 MPa for 7 days and 30.21 to 39.91 in the period of 28 days for 10.5% of Sewage Sludge Ash and 30% of GGBS content. When a compressive load reached a certain level of strength, concrete failure occurred. Which shown in Table No.2 Concrete compressive strength increased with increasing the ratio of GGBS and sewage sludge Ash content.

4.2 Split Tensile Strength:

The tensile strength of concrete was determined at the age of 7 and28 days as presented in graph. Fig No. 3

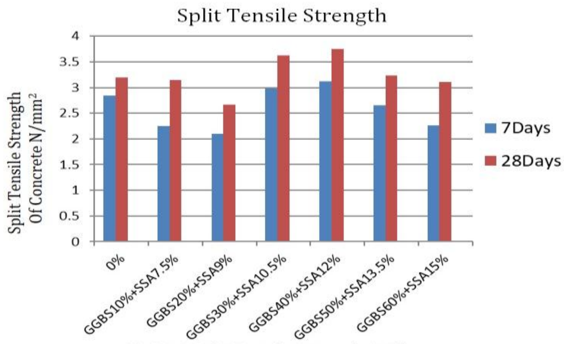

Fig No.3 Split Tensile Strength At The Age Of 7 & 28 Days Curing

represents split tensile strength of concrete with partial replacement of cement by GGBS 0%, 10%, 20%, 30%, 40%, 50%, 60% & SSA 7.5%, 9%, 10.5%, 12%, 13.5%, and 15%. There is an increase in split tensile strength for the replacement of GGBS and SSA. Maximum strength was obtained for 40% GGBS and 12% percentage of SSA replacement with cement. Test results show the split tensile strength varied from 2.84 to 3.12 MPa for 7 days and 3.2 to 3.75 in 28 days for 12% of SSA and 40% of GGBS content. When the load reached a certain level of strength, concrete failure occurred. Which is shown in table No 3.

Table No:-3 Average Compressive Strength (N/mm²)

Sr. No	GGBS %	Sewage Sludge Ash %	7Days	28Days
1	0%	0	2.82	3.2
2	10%	7.5	2.25	3.15
3	20%	9	2.10	3.67
4	30%	10.5	2.98	3.63
5	40%	12	3.12	3.75
6	50%	13.5	2.66	3.24
7	60%	15	2.26	3.11

4.3 Flexural Strength:

The flexural strength of concrete was determined at the age of 28 days.

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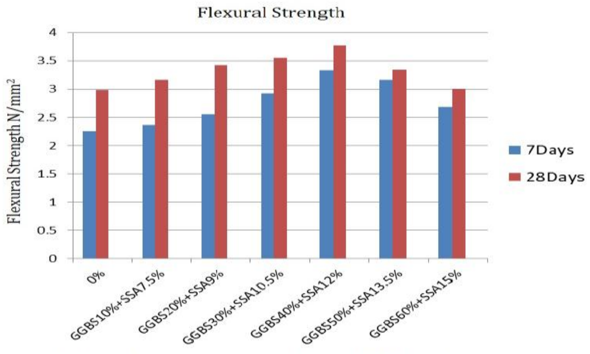

Fig No.4 Flexural Strength at the Age of 7 & 28 Days Curing

Fig 4 represents the 7 and 28 days' flexural strength of concrete with partial replacement of cement by 10%, 20%, 30%, 40%, 50%, 60% GGBS & 7.5%, 9%, 10.5%, 12%, 13.5% and 15% percentage of SSA. The flexural strength of GGBS and SSA-based concrete is increased which is higher than 40% GGBS and 12% SSA. Maximum strength is observed for 40% GGBS and 12% SSA. Test results show the flexural strength of concrete varied from 2.26 to 3.33 MPa for 7 days and 2.98 to 3.77 in 28 days for 12% of SSA and 40% of GGBS content.

Table No:-4 Average Compressive Strength (N/mm²)

Sr. No.	GGBS %	Sewage Sludge Ash %	7Days	28Days
1	0%	0	2.26	2.98
2	10%	7.5	2.37	3.16
3	20%	9	2.55	3.42
4	30%	10.5	2.92	3.55
5	40%	12	3.33	3.77
6	50%	13.5	3.16	3.34
7	60%	15	2.68	3.00

4.4 Slump Test:

Fig 5 represents the workability of the GGBS and SSA concrete mix. From this fig, it can be seen that as the percentage of GGBS increases the workability also increases.

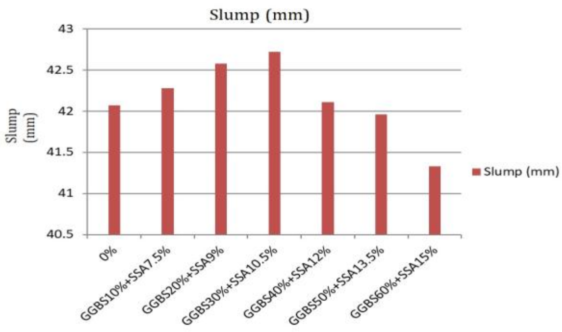

Fig.5 : Workability of GGBS variation with the Variation of SSA

5. CONCLUSIONS

Based on the experimental investigation the following conclusion is drawn

[1] SSA has been proven as an efficient pozzolana with properties similar to that of fly ash.

[2] Not much research is being carried out in India on SSA. Since India is a populous country with a huge production of sewage waste. If sewage sludge is converted to SSA, it can solve the problem of disposal of sewage to a considerable extent.

[3] Since the properties and composite of SSA depend upon the source, it is necessary to carry out a detailed characterization study on SSA.

[4] The workability of concrete was found to increase with the increase in SSA and GGBS in concrete.

[5] Maximum compressive strength was obtained for the replacement of cement by 30% GGBS and by 10.5% SSA.

[6] Maximum flexural strength achieved for cement replacement by 40% GGBS and sand by 10.5% SSA.

[7] Maximum split tensile strength is achieved for cement replacement by 40% SSA and by 10.5% GGBS.

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