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Strength Behaviour of Concrete Using GGBS & FLY ASH

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Abstract-Concrete is most used construction material in the civil engineering structure. Concrete is the world's most consumable product next to water. The Silica fume, Ground Granulated Blast Furnace Slag (GGBS) and Fly ash (FA) has been used as a partial replacement of cement in cement concrete. By utilizing these three products as a partial replacement of cement in cement concrete, the concrete can be made as Environmental friendly. In the present work, the effect of GGBS & fly ash on concrete in the hardened state is investigated and hardened properties of control concrete are compared with concrete made with GGBS and Fly ash. To test hardened properties Concrete cubes of size 150mm*150mm*150mm are casted and tested, for 7, 14 and 28 days, strength are found out. Control concrete of M40 grade and concrete with GGBS and Fly ash, cement is replaced by 5%, 10%, 15%, 20%, 25% of GGBS by its weight and Fly ash is varied from 5%, 10%, 15%, 20%, 25% by the weight of cement. Replacement of cement by 20% GGBS & 10% fly ash by weight of cement (mix M4) gives highest compressive strength of 39.56 N/mm^2, 43.78 N/mm^2, 46.33 N/mm^2 than control concrete at 7days, 14days & 28 days respectively.

Keywords: Concrete, construction material, fresh properties, Fly ash, hardened properties.

I. INTRODUCTION

Concrete as it is known today came into use in 1824 with the invention of Portland cement by Joseph Aspdin. Until then, pozzolanic binders i.e., lime-pozzolana mortars and concretes were used throughout the world. The large-scale production of ordinary Portland cement is posing environmental problems and also causing unrestricted depletion of natural resources. The raw materials used for the production of ordinary Portland cement are limestone, clay, silica, iron oxide materials and gypsum. The fuel for producing cement is coal. It is learnt that for every tonne of ordinary Portland cement produced, about one tonne of carbon dioxide is released into the atmosphere leads to global warming. Increased use of suitable industrial waste materials having pozzolanic characteristics that can replace energy consuming Portland cement is one of the ways to meet the challenge. Replacement of certain amount of Portland cement with industrial by-products such as GGBS, Fly ash, Silica fume derives the technical advantage of modification of the properties of the fresh and hardened concrete. This includes slower rate of setting and hardening, lower heat of hydration, improved durability in acidic environments. Industrial by-products that would otherwise be discarded as harmful environment pollutants can thus be efficiently used as cement replacement in concrete.

Many researchers have studied the effect of replacement of cement by silica fume and fly ash, rather than disposing to environment. Jayesh kumar et al.,[1]. Al., have studied the advancement of concrete technology can reduce the consumption of natural resources and energy sources and lessen the burden of pollutants on environment. Presently large amounts of fly ash are generated in thermal industries with an important impact on environment and humans. Many researchers have established that the use of supplementary cementitious materials (SCMs) like fly ash (FA), blast furnace slag, silica fume, metakaolin (MK), and rice husk ash (RHA), hypo sludge etc. can, not only improve the various properties of concrete - both in its fresh and hardened states, but also can contribute to economy in construction costs. Their research work describes the feasibility of using the thermal industry waste in concrete production as partial replacement of cement. The use of fly ash in concrete formulations as a supplementary cementatious material was tested as an alternative to traditional concrete. The cement has been replaced by fly ash accordingly in the range of 0% (without fly ash), 10%, 20%, 30% & 40% by weight of cement for M-25 and M40 mix. Concrete mixtures were produced, tested and compared in terms of compressive and split strength with the conventional concrete. These tests were carried out to evaluate the mechanical properties for the test results for compressive strength up to 28 days and split strength for 56 days are taken.

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Elsayed et al.,[2]. have studied the effects of mineral admixtures on water permeability and compressive strength of concretes containing silica fume (SF), fly ash (FA) and super pozz (SP) were experimentally investigated. Permeability of concrete was determined through DIN 1048 (Part 5). The research variables included cement type, ordinary Portland cement (OPC) or high slag cement (HSC), and mineral admixtures content was used as a partial cement replacement. They were incorporated into concrete at the levels of 5%, 10% and 15% for silica fume and 10%, 20% and 30% for fly ash or super pozz by weight of cement. Water-cement ratio of 0.40 was used and tests were carried out at 28 days. From the tests, the lowest measured water permeability values were for the 10% super pozz and 10% silica fume or 20% fly ash mixes. The highest compressive strength of concretes determined was for 10% silica fume mix with ordinary Portland cement and was reduced with the increase in the replacement ratios for other mineral admixtures than ordinary Portland cement concrete

Suman et al., (3) have studied is an attempt to find a suitable utilization for a particular fly ash depending upon its properties and thus reduce the need for vast areas for disposal of fly ash which in turn causes considerable damage to the environment. In India, around 110 million tones of fly ash get accumulated every year at the thermal power stations. Internationally fly ash is considered as a byproduct which can be used for many applications. Fly Ash mission was initiated in 1994 to promote gainful and environment friendly utilization of the material. One of the areas identified for its bulk utilization was in construction of roads and embankments. Concrete is being widely used for the construction of most of the buildings, bridges, etc throughout the world. Hence it is the backbone to the infrastructure development of a nation. India is taking major initiatives to improve and develop its infrastructure by constructing express highways, power projects and industrial structures. A huge quantity of concrete is required to meet out infrastructure development. Fly ash is a by-product of burned coal from power station. Considerable efforts are being taken worldwide to utilize natural waste.

II. MATERIALS AND METHODOLOGY MATERIALS

Cement: In this present work Aditya Birla cement of 53 grade ordinary Portland Cement(OPC) was used for casting cubes and cylinder for all concrete mixes. The cement was of uniform colour i.e. Grey with a light greenish shade and was free from any hard lumps. The various tests conducted on cement are initial and final setting time, specific gravity and compressive strength, Testing on cement was done as per IS codes. The specific and composting limits of Portland cement are reported in below.

Table 1. Test results on cement

SL.NO	Particulars	Experimental Results	As per standard IS:12269-2013
01	Specific gravity	3.15	------
02	Setting Time (Minutes)		
a)	Initial setting	150 min	30 Minutes (Minimum)
b)	Final setting	335min	600 Minutes (Minimum)
03	Compressive strength(MPa)		
a)	3 Days	32 MPa	27 MPa (Minimum)
b)	7 Days	45 MPa	37 MPa (Minimum)
c)	28 Days	44.20 MPa	43 MPa (Minimum)

Fine aggregate: The sand used for this project was locally procured M-sand and conformed to grading zone II as per IS: 383-1970. The Specific Gravity of natural sand was found to be 2.74. Fineness modulus is 2.91 and water absorption was found to be 1.3% and free moisture content was 0%.

Table 2. Sieve-Analysis on Fine Aggregate

Sieve Size mm	Percentage of Passing	Percentage of passing as per IS 383-1970 Reaffirmed on 2008			
		I	II	III	IV
10.00	100	100	100	100	100
4.75	95	90-100	90-100	85-100	95-100
2.36	85	60-95	75-100	85-100	95-100
1.18	70	30-70	55-90	75-100	90-100
0.60	46	15-34	35-59	60-79	80-100
0.30	18	5-20	8-30	12-49	15-50
0.15	5	0-10	0-10	0-10	0-10
Fineness Modulus=2.91					

Coarse aggregate: Coarse aggregates are those which are retained on IS sieve size 4.75 mm**.** The common coarse aggregates are crushed stone and gravel. Locally available crushed granite coarse aggregates are used in this study the tests for physical properties on coarse aggregates are conducted as per IS: 383-1970 the test results are shown in Table 3.6. Proper grading of aggregates is essential to get required strength as per design mix. Test on combined coarse aggregates grading is conducted as per IRC 44-1976. The test results are shown in table.

Fly ash: In this study, Class F fly Ash used is obtained from Raichur thermal power station, Shaktinagar. The

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chemical composition of fly ash and results of physical tests conducted on fly ash as given by suppliers are shown in table.

GGBS: In this study, GGBS used is obtained from Bellary Jindal steel works, Sandur. The chemical composition of GGBS and results of physical tests conducted on GGBS are given by suppliers are as shown in table

Water: Potable tap water is used for the preparation of specimens and for curing specimens.

Table 3. Tests results on coarse aggregate

Sl No	Particulars	Test results	Requirements as per IS: 383-1970
1.	Aggregate Impact Value, %	23.80	30% max for wearing surfaces
2.	Abrasion Value %	26.80	30% max for wearing surfaces
3.	Aggregate Crushing Value %	24.86	30% max for wearing surfaces
4.	Combined EI &FI Values,%	29.38	30% max
5	Specific Gravity	2.60	

Table 4 Chemical composition of Fly ash

Sl no	Elemental oxides	In (%)
01	Silicon Dioxide(SiO_2)	38.3
02	Aluminium oxide(Al_2O_3)	14.70
03	Iron oxide(Fe_2O_3)	19.48
04	Calciumoxide(CaO)	18.10
05	Magnesium oxide(MgO)	3.30
06	Potassium oxide (K_2O)	1.79
07	Sulphur Tri-oxide (SO_3)	1.50
08	Manganese oxide (MnO)	0.16
09	Titanium Di-oxide (TiO_2)	1.02

Table 5 Chemical composition of GGBS

Sl. No	Chemical Composition	In %
1.	Insoluble residue	0.46
2.	Magnesia content	7.92
3.	Sulphide sulphar	0.43
4.	Sulphate content	0.22
5.	Loss on Ignition	0.29
6.	Manganese content	0.15
7.	Chloride content	0.01
8.	Glass content	92
9.	Moisture content	0.15

III. CASTING AND TESTING METHODS

Casting of test specimen: Cube specimen of the concrete under study is cast and test conducted as per IS: 516-1999.cubes are cured for a period of 7, 14 and 28 days ,dried and tested immediately after removing from curing tank .This is because it gains strength at later age . The type and numbers of cast are shown in table.

Table 6 Conventional M40 grade concrete cubes

Sl. No	Type of specimen	Numbers	Mix Designation
1.	Conventional M40 grade concrete (M1) cubes	9	M0

Table 7 Ternary mix concrete cubes

Sl. No	Fly ash in %	GGBS in %	No of cubes	Mix Designation
1.	25	5	9	M1
2.	20	10	9	M2
3.	15	15	9	M3
4.	10	20	9	M4
5.	5	25	9	M5

Compressive Strength Test

Compressive quality is measured on materials, parts, and structures. By definition, a definitive compressive quality of a material is that estimation of uniaxial compressive anxiety achieved when the material bombs totally. The compressive quality is typically gotten tentatively by method for a compressive test. The contraption utilized for this investigation is the same as that utilized as a part of a malleable test. In any case, as opposed to applying a uniaxial pliable load, a uniaxial compressive load is connected.

Table 8 Compressive strength test results:

Mix Designation	Compressive strength (N/mm^2)		
	7 days	14 days	28 days
M0	35.76	39.21	45.68
M1	34.89	37.96	41.32
M2	36.12	38.24	43.67
M3	38.54	40.10	44.82
M4	39.56	43.78	46.33
M5	38.22	41.65	44.58

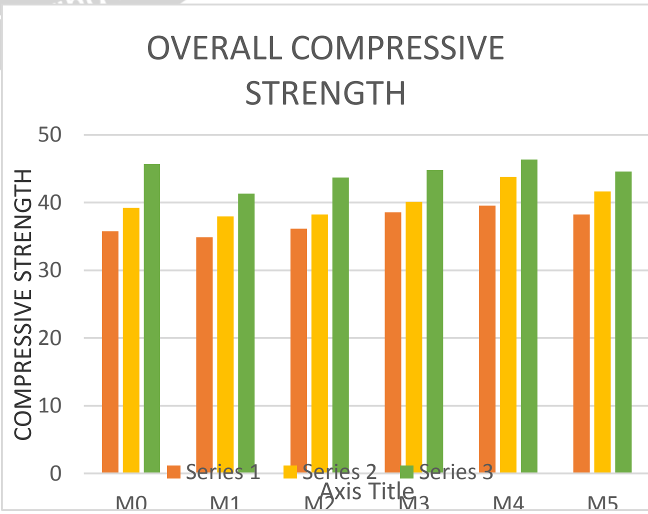

Fig 1. **Compressive strength test results**

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IV. Discussion

In the present work, the effect of GGBS & fly ash on concrete in the hardened state is investigated & the following observations were made from the experiments conducted.

The test results show that at 7 days curing period, the compression strength of mix M4 is higher than all mixes. The compressive strength of mix M1 is 1.23% less than control concrete but compressive strength of mix M2, M3, M4 & M5 is 1.01%, 3.68%, 5.05%, 2.84% higher than the control concrete.

At 14 days curing period also mix M4 is showing the highest compression strength and mix M1 is showing lower compressive strength. The compressive strength of mix M1 is 2.21%less than control concrete. But mix M2, M3, M4, M5 is showing better results than control concrete.

At 28 days curing period also the scenario remains same. Mix M2, M3, M4, M5 is showing better results than control concrete. But M1 is showing less compressive strength compared to control concrete.

From the experimental results of compressive strength of control concrete & concrete made with GGBS & fly ash it is noted that the addition of the two material helps in developing better strength compared to control concrete. Another important observation is that the compressive strength is higher in M4 concrete mix. And another important observation made in that percentage strength gain of mix M2, M3, M4, M5 is increased both in compression & split tensile at curing period of 14 days & 28days compared to 7 days the highest is being at 28 days. Since the pozzolonic activity proceeds slowly hence the greater strength is obtained at later ages.

V. Conclusion

1. Replacement of cement by 20% GGBS & 10% fly ash by weight of cement (mix M4) gives highest compressive strength of 39.56 N/mm^2, 43.78 N/mm^2, 46.33 N/mm^2 than control concrete at 7days, 14days & 28 days respectively.
2. The percentage strength gain is more at later ages than at the early stages.
3. Based on limited studies conducted we can conclude that both GGBS & Fly ash works in combination and can be considered as resourceful materials & can be used as a partial replacement for cement in concrete.
4. This investigation has shown that it is possible to use GGBS and FLYASH mixes concrete and achieve a similar strength that the conventional concrete. There is scope for further investigating this effect GGBS and FLYASH to further reduce the Portland cement content leading to greater economic and environmental advantages.

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