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Experimental Study on Mechanical Properties of Concrete with Partial Replacement of Cement by GGBS and Fly Ash

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Abstract- Cement industry is one of the major producer of carbon-dioxide, producing up to 7% of the worldwide emissions of this gas. After china (producing 2410millions metric tons of cement in 2016) India is the largest manufacturer of cement i.e., about 290million metric tons in 2016. For every tone of cement fabrication 900 Kgs of CO_2 is produced. To reduce the consumption of cement, we partially replaced the cement with Eco-friendly industrial solid waste materials like fly ash and Ground Granulated Blast Furnace Slag (GGBS) in M40 grade concrete with the replacement of 0%, 10 %, 15%, 20% & 25%. Mechanical properties like compression strength, split tensile strength and flexural strength are determined for 7, 28 days to study the behavior of concrete with these replacements.

Index Terms- Fly ash, GGBS, compression strength, flexural strength, split tensile strength, solid waste materials.

1. INTRODUCTION

Now a days concrete is most used material after the water, due to this cement production industries increases rapidly, hence it increases CO_2 content in the atmosphere. To reduce the high cement content used in huge constructions like dams, retaining walls, bridges etc. the replacements like GGBS (ground granulated blast furnace slag) and fly ash is used in concrete.

Fly ash is a finely divided residue which is obtained from thermal power stations by burning of coal. In India about 75 million tons of fly ash is producing per year, it is a serious environmental problem. Fly ash can simultaneously increase the workability of concrete due to the spherical shape of fly ash particles. The only way to reduce this issue is by using as replacement material in the construction industry. Fly ash is one of the common materials used in high performance and high strength concretes. About 30% of heat of hydration is reduced by using fly ash in the concrete. It also helps to decrease the permeability of the concrete. Colour of fly ash varies from light to dark grey depend upon carbon content and quality varies from source to source.

The fine slag obtained as a waste material from the blast furnace used to make iron and steel is GGBS .It can be added along with the Portland cement along with water and aggregate. Now a day's GGBS is a most widely using in Europe, United states and some Asian countries like Japan and Singapore because it increases the durability of the structures i.e., it increases the life span of the buildings. Concrete made with GGBS has low heat of hydration compared to other concretes. It also reduces the risk due to alkali-silica reaction and offers high resistance to corrosion, sulfate and other chemical attacks. GGBS is also used to limit the temperature rise in large concrete pours.

2. TEST MATERIALS

Cement:

Ordinary Portland Cement used is of 53 grade conforming to IS 12269-2015[3] , of specific gravity of 3.05 ,fineness of cement is like follows ordinary Portland cement properties, final setting time and initial setting time are satisfied according to the test conditions as per IS Code provisions. .

Table.1 Properties of Cement

S.No	Properties of cement	Test Results
1.	Normal consistency	32%
2.	Initial setting time	30min (aprox)
3.	Final setting time	10hrs
4.	Specific gravity	3.08
5.	Fineness of cement	8%
6.	Compressive strength	53

GGBS (Ground granulated blast furnace slag):

This material very fine powder like cement is collected from Vishakhapatnam, Andhra Pradesh. GGBS is used as direct replacement for Portland cement replacement. The fineness of the material is and specific gravity is 2.86 color of this material is white. As per the previous articles study the GGBS is increases the strength of concrete. GGBS cement is more economical than ordinary Portland cement. GGBS cement prevents the occurrence of efflorescence because of low lime content and less permeability.

Fly ash:

It is a byproduct from burning pulverized coal in electric power generating plants. Dosage rates depend upon the fly ash type and its reactive level rates Here class F fly ash is used of 10-25% dosage (this type of fly ash consists of only pozzolanic properties), it is taken from Vijayawada NTPS, AP. Fly ash produces various setting times and it resist the cold weather. Size of particles in fly ash is very small so it effectively fill the voids.

Conplast sp430:

Super plasticizer was used to prepare better workable mix design; the chemical dosage is of 0.8% of $1m^3$. We have tried with different dosages but finally got 0.8 -0.9% variation shows good results to attain workability, mechanical compressive strength and also uniformity of concrete.

Table.2 Physical properties of Fly ash

S.No	Properties	Results
1	Color	Whitish Grey
2	Specific Gravity	2.17
3	Bulk Density	601

Table.3 Chemical Analysis of Fly ash

S.No	Composition	% of Composition
1	Loss on Ignition	0.83
2	Silica as Sio_2	62
3	Iron Oxide as Fe_2O_3	4.23
4	Alumina as Al_2O_3	24.22
5	Manganese as Mn	0.54
7	Calcium Oxide as CaO	4.32
8	Magnesium Oxide as MgO	0.58
9	Alkalies (Soda as Na_2O & Potash as K_2O)	2.64
12	Sulphate as SO_3	0.64

Fine aggregates:

In this research work local river sand conforming to the zone III as per IS 383:1970[4] is used with water absorbing capacity of 0.8%, specific gravity of 2.71 and as per test results the fineness modulus is 3.25.

Coarse aggregates:

Crushed coarse aggregates of 20 mm sized from local quarry. The specific gravity of aggregates is 3.01, water absorbing capacity of 0.45% and fineness modulus is 6.32

Water:

Water is a main component in the concrete and its least expensive, it plays a major role for obtaining strength of the concrete through hydration process General tap water which is free from salts and other impurities such as acids, oils etc. is used for both mixing and curing of concrete. Generally properties of tap water studied in laboratory to check the suitability for making of concrete.

Table.4 Chemical Properties of Water

S.no	Parameters	Test Results
1.	P_H	7.35
2.	T.D.S	960 ppm
3.	Alkalinity	290 ppm
4.	Chloride	118 ppm
5.	Hardness	202 ppm

3. MIX DESIGN

After several trail mixes, a proportion for conventional M40 grade concrete was designed as per IS 10262:2009.GGBS and fly ash were used as replacing materials for cement. The percentage replacement by weight of cements includes 0%, 10 %, 15%, 20% & 25% trails. A super plasticizer, conplast sp430 with 0.8 % of dosage was used in every trail mix. Water to cement ratio is maintained constant as 0.4 for all mixes. The concrete mixes with specified details of mix proportions are presented.

Mix proportions for characteristic strength of M40 N/mm2 and target slump of 100 mm were prepared as per IS 10262:2009[18], Table 2.Concrete cubes were casted in agreement with IS 516:1959 [20] confirming to ASTM C192. Three cubes of 150 mm x 150 mm x 150 mm were prepared for each trail mix to check the characteristic compressive strength and the results are presented in the document. The materials were mixed in a drum mixer of 1 cum capacity. The materials used were of saturated surface dry condition. Half the coarse aggregate and fine aggregate and cement were set for dry mixing in the first phase. Later remaining coarse aggregate is added and dry mixing is done for one minute. The water was then added and the concrete was set for further mixing for three minutes to get consistent mass.

Workability tests conducted on concrete:

1. Slump cone apparatus
2. Compaction factor test

To found the nature of concrete performed the above two tests. These tests had given good results of workability such as slump flow is more or less 100mm

and compaction factor also give good results within the permissible limits, but the workability of concrete of partially replaced with mineral admixture is decreased, which compared to the conventional concrete because of added mineral additives content.

Mixing:
The mixing of concrete is done by using drum mixer of cum capacity. The individual weights of all the ingredients viz., cement, fly ash, GGBS, FA and CA were noted. These are thoroughly mixed by adding design quantity of water along with admixture in specified dosage in drum mixer.

Percentages of mix replacements:

3. TEST PROCEDURE

Test for Compressive strength of concrete:
Of all the tests applied to the concrete, compressive strength test is the most important test to determine the characteristics of the concrete. The standard 150mm x150mm x 150mm size specimens were used for this test. The concrete cubes were tested using CTM of capacity 2000kN in our laboratory. The load was applied axially on casted cubes. The load at which the specimen fails is noted as ultimate load. The compressive strength was obtained by using the formula, f_{ck}= P/A where,f_{ck}= Characteristic compressive strength, P = Cube compressive load causing failure in N, A = Cross sectional area of cube in mm^2. the average of all the strengths of the specimens are calculated and it is taken as Characteristic compressive strength of concrete. The cylinders of standard size (150mm*300mm) were also casted and tested using CTM and after applying axial load, the compressive strength is calculated using the same formula

Fig.1 Compressive testing machine

Test for Flexural strength of concrete:
Flexural strength is defined as the ability of the material to resist the deformation under the load. It is also known as modulus of rupture which is a mechanical property for a brittle material. The specimens of standard size 100mmx100mmx500mm were used for this test and are tested using flexural testing machine as shown in figure. The load at which the specimen fails is noted. The flexural strength of the concrete beams is calculated by using the formula,

$$f_b = \frac{PL}{bd^2}$$

Where P = Failure load, L= distance between the roller supports center to center of the machine, b=breadth of the specimen, d= depth of the specimen.

Fig.2 Flexure testing machine

Split tensile strength of concrete:-
Cylinders with standard dimensions were casted with various percentage variations and are tested in universal testing machine having a capacity of 200MT as per IS 516 – 1959.
Tensile strength of concrete is taken as fs= 2P/πlD
.

4. EXPERIMENTAL RESULTS AND DISCUSSIONS:

Compressive strength of concrete for cubes and cylinders:
From the results of compressive strength of concrete the compressive strengths of different mixes by names M2, M3, M4, M5 for 28 days are 34.67Mpa, 36.17Mpa, 50.33Mpa, 33.33Mpa respectively for cubes. It was observed that for the mixes M2 and M3 there is a noticeable variation in the strengths compared to the standard mix (48.3 Mpa). But, for mix M4 there is a steep increase in the strength and reaches to maximum strength when compared to all mixes including reference mix (M1) (50.33 Mpa) and for the mixes greater than M4 there is steep reduction in strengths.

Hence, it can be concluded that mix M4 gives maximum strength when compared to other mixes. The same results are observed even in case of cylinders when tested for compressive strength.

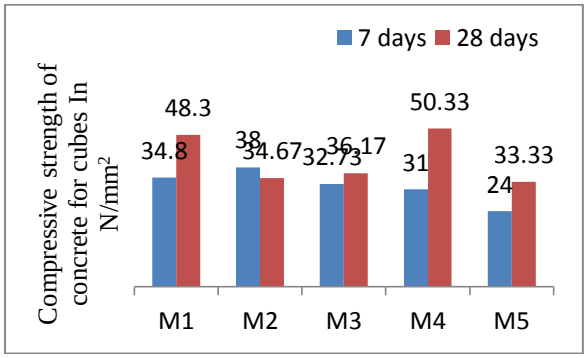

Fig.3 Compressive strength of Concrete for cubes

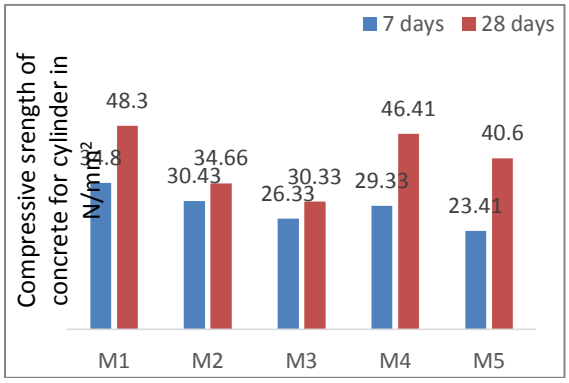

Fig.4 Compressive strength of Concrete for Cylinder

Flexural strength of concrete for prisms:

In reference to the bar chart cited above, the flexural strengths of concrete are 4.89 Mpa, 4 Mpa, 5.3Mpa, 3.99 Mpa for the mixes M2, M3, M4 and M5 for 28 days. The results obtained are similar to that of the results of the compressive strength. Maximum strength is obtained at mix M4 (5.3 Mpa). Beyond this mix there is a decrease in the strength with respect to the 0% mix.

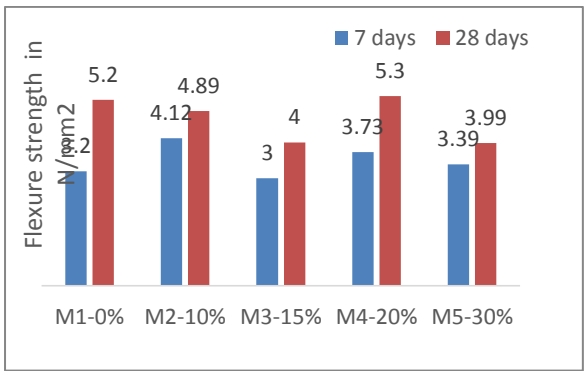

Fig.5 Flexural strength of Concrete

Split Tensile strength of concrete:-

The split tensile strength is conducted on the cylindrical specimens of dimensions 100 mm diameter and 300 mm length for 28 days. The results obtained are varying in strengths when compared to the compressive strengths and flexural strength. At the mix M3 (4.83 Mpa) uniform strength is developed with reference mix (4.71 Mpa) the remaining mixes are descending in strengths with the standard mix.

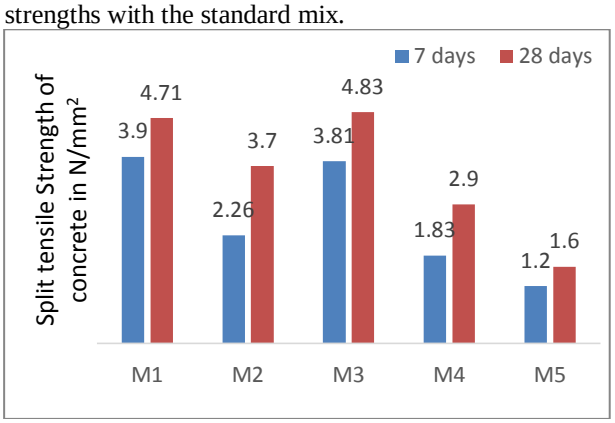

Fig.6 Split Tensile strength of Concrete

5. RESULTS AND DISCUSSIONS:

Flexural strength vs compressive strength

The variations in the theoretical flexural strengths obtained from the formula shown below and the flexural strengths originally obtained after testing the beams are tabulated as follows.

Flexural strength = $0.7\sqrt{f}_{ck}$

Table.5 Flexural strength vs compressive strength

S.no	Compressive strength		Flexural strength	OFS
1	0%	48.3	4.86	4.86
2	10%	34.67	4.12	5.00
3	15%	36.17	4.2	4.99
4	20%	50.33	4.96	5.10
5	30%	33.33	4.04	3.99

OFS-Obtained Flexural Strength

6. CONCLUSIONS

1. The workability of concrete is reduced compared to the normal concrete because of addition of mineral admixtures such as fly ash and GGBS
2. In this research work it is observed that the compressive strength is decreased in early age (7 days) when compared with the conventional concrete, but finally attained the target strength after complete curing period of 28 days.
3. The strengths of the split tensile and flexural strength of concrete follows the same principal existed in the compressive strength of the concrete.

4. A remarkable increase in strength is observed till 20 % addition of mineral admixture, but it is observed to be decreasing after that limit.
5. The flexural strength has no major deviations in all percentage of mixes.
6. In split tensile strength of concrete, remarkable variation is observed at replacement of 15% (GGBS + fly ash).
7. There is a steep decrease in the strength beyond 20% of replacement.
8. It can be observed that the replacement up to 20% yields same results as that of nominal mix(with respect to the nominal mix).

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