Investigation on Mechanical and Durability Properties of Fly Ash and Slag based Concrete

Dr. B. Vidivelli[#1], S. Sri Durga Meru[*2]

[#1]*Professor & Department of Civil & Structural Engineering & Annamalai University, Chidambaram, India.*

[*2]*M.E. Student & Department of Civil & Structural Engineering & Annamalai University, Chidambaram, India.*

Abstract

There has been a tremendous increase in the use of mineral admixture by industries during the late 20th century and the rate is expected to increase. Concrete is an artificial material, which is made up of cement, fine aggregate, coarse aggregates and water. The increasing demand for cement and concrete is met by the partial cement replacement by addition of supplementary cementing materials which leads to several improvements in the concrete composites and to the overall economy. Mineral admixtures are used in concrete because they improve the properties of concrete. The lower cement content leads to a reduction for CO_2 generated by the production of Portland cement. In this study an attempt is made to replace cement with fly ash 20% as constant and GGBS with 10%, 20%, 30%, 40%, 50% for M30 grade concrete and the properties of fresh and hardened concrete are to be tested at 7 and 28 days to identify the optimum percentage of GGBS in concrete. Replacement of cement by fly ash and GGBS in M30grade concrete to study compressive strength (28, 56, 90 and 180 days), flexural strength and modulus of elasticity for concrete. Also determine the durability properties such as rapid chloride penetration test, salt resistance and sulphate resistance properties. The multi linear regression equations are to be derived by using the origin pro analysis for the properties of concrete.

Keywords — *Fly ash, GGBS, Compressive strength, Flexural strength, E for concrete, Rapid Chloride Penetration test, Salt resistance and Sulphate resistance.*

I. INTRODUCTION

Concrete is one of the most widely used construction material. Portland cement Production is a major contributor to carbon-di-oxide emission. The global warming is caused by the emission of greenhouse gases, such as carbon -di-oxide, to the atmosphere by human activities. Many efforts are being made in order to reduce the use of Portland cement in concrete. These efforts includes the utilization of supplementary cementing materials such as fly ash, alccofine, silica fume, ground granulated blast furnace slag, ceramic powder etc. and finding alternative binders to Portland cement. The properties of various types of Portland cement differ because of relative proportions of the components and the fineness to which the cement clinkers is ground. The ordinary Portland cement or the setting cement is the basic Portland cement and is manufactured in larger quantities than all the others. Fly ash is a naturally coal combustion by product. It is extracted by the precipitators in the smokestacks of coal-burning power plant to reduce pollution. About 120 coals based thermal power stations in India are producing about 112 million tones fly ash per year. With the increasing demand of power and coal being the major source of energy, more and more thermal power stations are expected to be commissioned/augment their capacities in near future. Fly ash has been consider as a “Pollution Industrial Waste” till about a decade back and was being disposed off in ash ponds. According to ASTM C-618fly ash is broadly classified into two types, Class F and Class C fly ash. The chief different between these two classes is the amount of calcium, silica, alumina, and iron content. The chemical properties of fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite). Fly ash makes concrete denser, and hence less permeable, mainly by reduced water cement ratio and improved microstructure of concrete. At the same time, fly ash improves long term strength of concrete due to the continuous pozzolanic reaction. In the past, fly ash produced from coal combustion was simply entrained in flue gases and dispersed in to the atmosphere. This created environmental and health concerns that prompted laws which has reduced fly ash emissions to less than 1% of fly ash produced. Worldwide more than 65% fly ash produced by coal power stations is disposed of in landfills and ash ponds. In India alone, fly Ashland fill covers an area of 40,000 areas (160 Km^2). The recycling of fly ash has become an increasing concern in recent years. Ground Granulated Blast Furnace Slag is made up the largest portion of by-products from the blast-furnances used to make iron. These operate at a temperature of about 1,500 degree centigrade and are fed with carefully controlled mixture of iron-ore, coke and limestone. The iron ore is reduced to iron and the remaining materials from a slag that floats on top of the iron this slag is periodically tapped off as a molten liquid and if it is to be used for the manufacture of GGBS it has to be rapidly quenched in large volumes of water. The material is smaller than 4.75 mm size is called fine aggregate. Natural sands are generally used as fine aggregate. Sand may be obtained from pits, river, lake and sea shore. When obtained from pits, it should be washed free it from clay and silt. Sea shore sand may contain chlorides which may cause efflorescence, and may cause corrosion of reinforcement. Material obtained on 4.75mm sieve is termed as coarse aggregate crushed stone and natural gravel are the common materials used as coarse aggregate for concrete. Natural gravels can be quarried from pits where they have been deposited by alluvial or glacial action, and are normally composed of flint, quartz, schist and igneous rocks. Potable, clean and fresh water of PH value 7 has been used for entire casting and curing of specimens. Conplast 430 super plasticizer used as a water reducing admixture. Conplast 430 is based on sulphonated naphthalene polymers and supplied as a brown liquid instantly dispersible in water. They are many uses available in the water reducing admixture. The main thing is to produce high strength, high grade concrete M25and above by substantial reduction in water resulting in low permeability and high early strength. In this study, reactions, utilization and availability of materials to be studied. From this information fly ash and GGBS is replaced for cement. In other chapters will be discussing in the properties of materials and strength of M_{30} grade concrete, durability study and regression analysis.

A. Literature Collection

This literature study explains the experimental assessment on properties of concrete using fly ash and GGBS. Their impact on the compressive strength and durability were studied. The results showed that the concrete mixtures with GGBS and fly ash perform better than the conventional concrete. Amit et al, **(2016)** had described that, GGBS was added two different mix proportion to partially replace the cement with (40 & 60%).The specimens were tested by workability, compressive strength and flexural strength. Biswadeeop, **(2015)** had investigated, the experimental test for carrying out to understand the fresh and hardened properties of self-compacting concrete, in which cement replaced by GGBS and fly ash in various mix proportions for M30 grade concrete. The strength behavior, flexural behavior and split tensile strength behavior of SSC were studied. Azizul et al, **(2014)** had described the use of optimum level of palm oil fuel ash (POFA), ground granulated blast furnace slag (GGBS) and low calcium fly-ash (FA) with manufactured sand (M-sand) to produce geopolymer mortar. Eleven mixtures were prepared with varying binder contents with the POFA content varying between 25% and 100%; the other constituent materials such as fine aggregate and water were kept constant. Hiroshi et al, **(2014)** had investigated that, GGBS was added in different mix proportion like 15%, 30% & 45% to partially replace by the cement. The specimens were tested by compressive test, chloride ingress test & carbonation test. The test results indicated the 30% replacement of cement with GGBS give better results, and the tendency for higher GGBS additional to promote carbonation.

B. Objectives

From these literatures the following scope are described.

- Determine the mechanical properties of replacement materials.
- Determine the durability properties of replacement materials.
- To investigate the Properties of concrete would be analyed using regression equation. To design the M30 concrete mix as per 10262:2000.
- To study the replacement material characteristics as per Indian Standard,
- To study the workability characteristics of conventional concrete and material replacement concrete by the slump cone test.
- To find the percentage of replacement material from 28 days compressive strength of concrete.
- To determine the mechanical property such as compressive strength, flexural strength, modulus of elasticity for concrete.
- To study the durability properties such as rapid chloride penetration test, salt resistance test and sulphate resistance test.

II. MATERIALS

Cement, fine aggregates, coarse aggregates, fly ash and GGBS used to the casting of specimens.

A. Cement

Ordinary Portland cement 53 grade is used in the experimentation for concrete.

B. Fine aggregate

River sand is used as fine aggregate confirming to IS: 383-1970 of Zone III for concrete cube specimens.

C. Coarse aggregate

Crushed angular granite coarse aggregate confirming to IS: 383-1970 is used. Nominal 20 mm size aggregate is used in concrete.

D. Ground granulated blast furnace slag (GGBS)

Ground granulated blast-furnace slag also called slag cement, is made from iron blast-furnace slag; it is a non-metallic hydraulic cement consisting essentially of silicates and alumina silicates of calcium developed in a molten condition simultaneously with iron in a blast furnace. The molten slag at a temperature of about 1500°C is rapidly chilled by quenching in water to form a glassy sand like granulated material. The granulated material is ground to a fine powder. The GGBS are purchased from welcome chemicals company, Pondicherry.

E. Fly ash (class C)

Class C fly ash which is lignite based is available in plenty at Neyveli lignite corporation (NLC) where structural is utilization is seldom thought off. Fly ash for structural concrete using class C fly ash is not under consideration due to the ill effects of fly ash with the reinforcing steel. Therefore, a preliminary study on high volume utilization of such high calcium class C fly ash of NLC has been proposed and initiated.

F. Mix Proportions

Mix proportion was confirmed by the trial mixes. Target slump value is 50-75 mm. In the Table 4.3 shows the mix IV gives the slump value 60 mm. Slump tests is conducted by the fresh concrete. Figure 4.1 shows the slump value of M30 grade of concrete. The final mix proportion is 1:1.415:2.9.

III.RESULTS AND DISCUSSION

A. Mechanical Properties

This is deals with the results obtained from the various experiments conducted to assess the mechanical properties of concrete. The aim of the study to determine the compressive strength, flexure strength and modulus of elasticity of the concrete and to determine the weight loss for sulphate attack test, salt resistance test and determine the RCPT test also for various mix proportions.

1) Compressive Strength:

The test was carried out confirming to IS 516-1959 to obtain compressive strength of concrete. The cubes were using CTM. The compressive strength test results exhibits the mixes conventional and 20% fly ash and 40% GGBS are 38.50 N/mm2, 42.52 N/mm2 at the age of 28 days. The compressive strength increases the percentage of 10.44% for 28 days. Similarly, the mixes conventional and 20% fly ash and 40% GGBS are 38.99 N/mm2, 50.52 N/mm2 at the age of 56 days. The compressive strength increases the percentage 23.5% for 56 days with respect to conventional concrete. The result of compressive strength was presented in the Table 4.7. There is a significant improvement in the compressive strength of concrete because of the high pozzolanic nature of the GGBS and its voids filling ability. Figure 4.10 shows comparison for the compressive strength at the age of 28 and 56 days both conventional and replacement. From this compressive strength results indicates the replacement of cement with fly ash (20%) and GGBS (40%) gives maximum strength at the age of 28 and 56 days.

Table 1 Compressive strength for all mixes

Materials	Average Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
Conventional	38.50	38.99
Replacement Fly ash 20% GGBS 40%	42.52	50.99

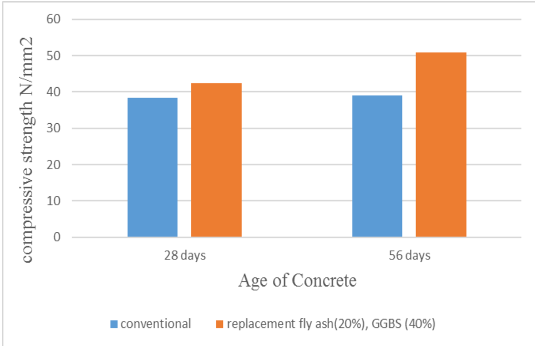

Fig. 1 Compressive Strength Test Result

2) Flexural Strength:

The test was carried out confirming to IS 516-1959 to obtain flexural strength of concrete. The compressive strength test results exhibits the mixes conventional and 20% fly ash and 40% GGBS are 4.2 N/mm2, 4.3 N/mm2 at the age of 28 days. The flexural strength increases the percentage of 2.38 % respectively with respect to conventional concrete. The result of flexural strength was presented in the Table 4.8. The flexure strength test results are plotted as shown in the Figure 2. From this results indicates the flexural strength is increasing the replacement of cement with fly ash (20%) and GGBS (40%) at the age of 28 days.

Table 2 Flexural Strength for Both Conventional and Replacement

Mix	Avg. Flexural strength (N/mm^2)
Conventional concrete	4.2
Replacement Fly ash 20% GGBS 40%	4.3

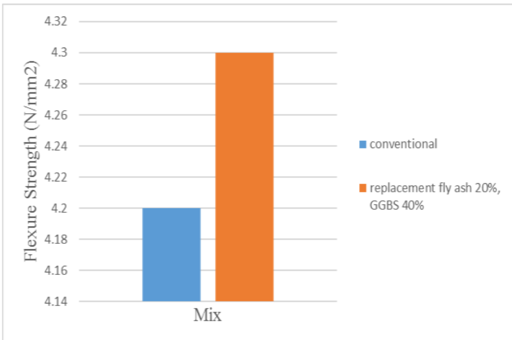

Fig. 2 Flexural Strength Result

B. Durability Properties

1) Sulphate Resistance Test

The sulphate attacked test parameters observation was presented for the strength and mass loss of conventional and replacement concrete. The Table 3 shows the compressive strength loss of sulphate solution. From the sulphate resistance the weight loss for conventional and replacement fly ash 20%, GGBS 40%is 0.209 and 0.163%. The replacement material is lesser weight loss compare to conventional concrete. The weight loss is 0.164 in percentage. The strength loss of conventional and replacement respectively 2.9 and 2.3 in percentage.

Table 3 Weight and Strength Loss for Sulphate Solution

Mix	Average compressive strength (N/mm^2)		Strength loss in percentage
	Before immersion of sulphate	After immersion of sulphate	
CC	38.50	37.37	2.9
M5	42.52	41.54	2.3

2) *Salt Resistance Test*

The salt attacked test parameters observation was presented in the table 4.12 in this table also shows the strength and mass loss of conventional and replacement concrete. The average loss of weight and loss of compressive strength is considerable low. GGBS in concrete could be reasonable in the aspects of more salt resistance. From the salt resistance the weight loss for conventional and replacement fly ash 20%, GGBS 40% is 0.21 and 0.167%. The replacement material is lesser weight loss compare to conventional concrete. The weight loss is 0.16 in percentage.

Table 4 Weight and Strength Loss for Salt Solution

Mix	Average compressive strength (N/mm^2)		Strength loss in percentage
	Before immersion of sulphate	After immersion of sulphate	
CC	38.50	37.37	2.9
M5	42.52	41.43	1.8

3) *RCPT Result*

On addition of GGBS in OPC system, RCPT value decreases, this is due to (1) particle size is smaller so the resulting in lower permeability. (2) Addition of alumina decreases RCPT value because alumina reacts with chlorine preferentially to calcium. On addition of GGBS in fly ash based cement, there is further reduction in RCPT value, this due to the higher amount of pozzolana.

Table 5 Weight and Strength Loss for Salt Solution

Mix	Charge passed (coulombs)	Average charge passed (coulombs) Q	Chloride permeability rating
Conventional concrete	1627.2	1747.8	Low
	1868.4		
Replacement fly ash 20% GGBS 40%	534.6	661.5	Very low
	788.4		

Rapid chloride penetration tests the chloride penetration in 20% fly ash and 40% GGBS were decreases 62.5% respectively with respect to conventional concrete. The chloride penetration is very low in replacement was 661.5 coulombs. In the concrete indicating lesser permeability in concrete as per standard. So, the addition of fly ash and GGBS reduce the chloride penetration. Because of the particle size is smaller so the resulting in lower permeability.

This chapter deals with the experiments done to determine the mechanical properties such as compressive strength, flexural strength and modulus of elasticity of concrete and also determine the durability properties such as sulphate resistance, salt resistance and rapid chloride penetration test. The test results and discussion presented in this chapter. The multi linear regression equation formed in next chapter using data analysis.

IV. REGRESSION ANAYSIS

Regression analysis is using origin pro software, Multi linear regression analysis is used for this study. The dependent and independent variables used for creating the regression equation. The dependent variables are Compressive strength and Flexural strength for normal, external and internal curing at 28 days and 56 days.

The Independent variables are Cement (C), Flyash (FA), GGBS (GG), superplasticizer (SP) and weight of specimen (wt). In this analysis predicted values are determined and also compared the experimental and predicted values. The regression equation analysed for compressive strength of concrete for 7 days, 28 days and 56 days.

The R2 value is best fit for experimental values. So there is a good agreement for experimental and predicted values of concrete.

Table 6 Input and Output Data Used for Compressive Strength at 28 Days

Mix	Cement (kg/m^3)	Fly ash (kg/m^3)	GGBS (kg/m^3)	SP (lit/m^3)	Weight of cube (kg)	Compressive strength (N/mm^2)	
						Experimental	predicted
CC	432	0	0	1.29	8.761	39.5	39.76078
	432	0	0	1.29	8.498	38.44	37.37528
	432	0	0	1.29	8.607	37.56	38.36395
M5	204.874	65.25	161.876	1.64	8.839	44.31	43.35447
	204.874	65.25	161.876	1.64	8.677	40.90	41.88508

	204.874	65.25	161.876	1.64	8.725	42.35	42.32045

Table 7 Input and Output Data Used for Compressive Strength at 56 Days

Mix	Cement (kg/m^3)	Fly ash (kg/m^3)	GGBS (kg/m^3)	SP (lit/ m^3)	Weight of cube (kg)	Compressive strength (N/mm^2)	
						Experimental	predicted
CC	432	0	0	1.29	8.725	38.04	38.89661
	432	0	0	1.29	8.256	39.15	39.2029
	432	0	0	1.29	8.765	39.78	38.87049
M5	204.874	65.25	161.876	1.64	8.763	53.82	50.97737
	204.874	65.25	161.876	1.64	8.645	50.44	51.05443
	204.874	65.25	161.876	1.64	8.823	48.71	50.93819

V. CONCLUSIONS

Portland cement production is a major contributor to carbon-di-oxide emission. So need the alternative materials for cement. In this study, the cement replaced with fly ash and GGBS. Preliminary test such as specific gravity of cement, fine aggregate, coarse aggregate, fly ash, GGBS are carried out and found fit for IS code. From the experimental investigation and regression analysis, the following conclusions were drawn.

- The maximum compressive strength was achieved by replacement concrete by fly ash (20%) and GGBS (40%) and increased 10.44 % at 28 days with respect to conventional concrete.
- The maximum compressive strength was achieved by replacement concrete by fly ash (20%) and GGBS (40%) and increased 30.7% at 56 days with respect to conventional concrete.
- The flexural strength was achieved by using fly ash (20%) and GGBS (40%) concrete and increased 2.38% higher than the conventional concrete.
- The modulus of elasticity of concrete was achieved by using fly ash (20%) and GGBS (40%) concrete and increased 20% higher than the conventional concrete.
- From the salt attack test result, the replacement of fly ash and GGBS concrete obtained the weight loss of 19.05 % decreased with respect to conventional concrete and the strength loss also decreased 25% with respect to conventional concrete.
- From the sulphate attack test result, the replacement of fly ash and GGBS concrete obtained the weight loss of 20% decreased with respect to conventional concrete and the strength loss also decreased 20.6% with respect to conventional concrete.
- From RCPT test results reveals that the fly ash 20 % and GGBS 40 % of mix chloride penetration was very low when compared to the conventional concrete.
- Good convergence was obtained between the experimental results and those predicted through regression analysis.
- It recommended to utilize the fly ash and GGBS material with cement after checking its other durability properties and flexural studies on beams.

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