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Effect of Fly Ash and Nano GGBS on the Properties of the High Strength Concrete

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ABSTRACT

The usage of mineral admixture in concrete is rising with regards to socio-economic understanding, energy conservation, and environmental protection, as well as for enhanced engineering and performance of concrete. However, more usage of supplementary cementitious material in concrete is restricted due to lack of gain in strength at early ages. In this present research, an attempt has been made to investigate the effect of partial replacement of cement with various percentages of nano GGBS and combination of nano ggbs & fly ash on mechanical properties and chloride permeability. Cement was replaced with GGBS in the proportions of 30%, 40%, 50%, 60% respectively and ggbs as constant at 30%, fly ash varying 10%, 20%, 30% respectively. It has been observed that, the compressive strength of concrete is decreasing at all days and at early ages, particularly with the increasing replacement of GGBS. To compensate the loss in strength, nano particles of ggbs and micro fly ash which is silica rich material have been blended with cement during mix preparation of concrete. The effect is considered by comparing the results of compressive strength, tensile strength and chloride permeability of high strength concrete.

Key words: ***Ground granulated blast furnace slag (GGBS), fly ash, mechanical properties, chloride permeability***

1. Introduction: During recent years, nano technology is developing with an ascending rate. Due to the new uses of nano particles there is an interest in the investigation of nano particles especially in concrete. Concrete is obtained by mixing cementitious materials, water, aggregate and sometimes admixtures in required proportions. Fresh concrete or plastic concrete is freshly mixed material which can be molded into any shape hardens into a rock-like mass known as concrete. The history of high strength concrete is about 35 years old, in late 1960s the invention of water reducing admixtures lead to the high strength precast products. In India high strength concrete is used in prestressed concrete bridges of strength from 35 MPa to 45 MPa. Concrete strength of 75 MPa is being used for the first time in one of the flyover at Mumbai. Also in construction of containment Dome at Kaiga power project used HPC of 60MPa with silica fume as one of the constituent. The reasons for these demands are many, but as engineers, we need to think about the durability aspects of the structures using these materials. With long term durability aspects kept aside we have been able to fulfill the needs.

The objective of the present work is to develop concrete with good strength, less porous, less permeability so that durability will be reached. For this purpose it requires the use of different pozzolanic materials like fly ash, nano ground granulated blast furnace slag.

2. Literature Review:

When used with Portland cement, the calcium hydroxide liberated from the Portland cement reacts with the alumina-silicates present in the fly ash to form cementitious compounds with cohesive and adhesive properties. This pozzolanic reaction, however, is much slower than cement hydration reactions. Because of this, partial replacement of cement with fly ash results

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in the release of heat over a longer period of time. The concrete temperature remains lower because heat is dissipated as it is evolved. With an increase in the amount of fly ash used as cement replacement, the rate of heat release is slowed down, resulting in a lower maximum temperature in the concrete mass compared to the concrete containing no fly ash (Joshi and Lohtia, 1997).

However, since different fly ashes have different chemical compositions, the level of replacement should increase with the calcium content of fly ash to achieve equal reductions in temperature (Thomas, et al., 1995). High calcium fly ashes do not necessarily cause reduced heat evolution (Malhotra and Mehta, 1996).

GGBS hydrates are generally found to be more gel-like than the products of hydration of Portland cement, and so add denseness to the cement paste. When GGBS is mixed with water, initial hydration is much slower than Portland cement mixed with water.

Therefore, Portland cement or alkali salts or lime are used to increase the reaction rate. Hydration of GGBS in the presence of Portland cement depends largely upon breakdown and dissolution of the glassy slag structure by hydroxyl ions released during the hydrations of the Portland cement.

3. Material properties:

3.1. GGBS: Ground Granulated Blast furnace slag (GGBS) is a by-product for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. Here the molten slag is produced which is instantaneously tapped and quenched by water. This rapid quenching of molten slag facilitates formation of “Granulated slag”. Ground Granulated Blast furnace Slag (GGBS) is processed from Granulated slag. If slag is properly processed then it develops hydraulic property and it can effectively be used as a pozzolanic material.

Table1: Chemical composition (%) of GGBS

SiO2	39.18
Al2O3	10.18
Fe2O3	2.02
CaO	32.82
MgO	8.52
Na2O	1.14
K2O	0.30

3.2. FLY ASH: Any country's economic & industrial growth depends on the availability of power. In India also, coal is a major source of fuel for power generation. About 60% power is produced using coal as fuel. Indian coal is having low calorific value (3000-3500 K cal.) & very high ash content (30-45%) resulting in huge quantity of ash is generated in the coal based thermal power stations. During 2005-06 about 112 million tons of ash has been generated in 125 such power stations. With the present growth in power sector, it is expected that ash generation will reach to 175 million tons per annum by 2012. Fly ash produced in modern power stations of India is of good quality as it contains low sculpture & very low unborn carbon i.e. less loss on ignition.

Table2: Chemical composition (%) of Flyash

Compound	Content %wt
SiO2	59
Al2O3	21
Fe2O3	3.7
CaO	6.9
MgO	1.4
SO3	1
K2O	0.9
LOI	4.62

3.3. Cement: In the present investigation, commercially available 53 Grade ordinary Portland cement was supplied by Zuari Cement with Specific

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Gravity of 3.1 and Fineness modulus of 290 m^2/kg was used for all concrete mixtures.

3.4. Aggregates: Crushed sand with a specific gravity of 2.65 and fineness modulus of 2.83 was used as fine aggregate and crushed aggregate from Hastavaripalli crusher of specific gravity of 2.61 was used as coarse aggregate. Two different classes of coarse aggregate fractions were used: 10-4.75 mm and 20-10 mm.

4. Experimental program and Mix Proportions:

4.1 Mix proportion: While designing mix proportion for HSC for the required strength, it is necessary to know the efficiency of the mineral admixture used at its different replacement levels and ages. When the efficiency factor is known, then the cement content can be reduced according to the equivalent cement content of each mineral admixture. Therefore, it is necessary to know the effectiveness of different admixtures towards the development of strength, and also their optimum replacement. The proposed mix design is based on the efficiency factor of fly ash and GGBS at different replacement levels.

Table3: Mix proportions of the concrete

No	1	2	3	4	5	6	7	8
ggbs(kg/m³)	0	137	183	228	275	137	137	40
Flyash(kg/m³)	0	0	0	0	0	45	92	30
Sand (kg/m³)	720	720	720	720	720	720	720	30
CA 20mm 10mm	645 430	645 430	645 430	645 430	645 430	645 430	645 430	183
								137
								137
								720
								645 430
Sp	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5

4.2.Casting and Curing of Specimens: IS standard 150mm Cubes, 150mm X 300mm cylinder and 100mmX50 mm were cast from each mixture to evaluate compressive strength and toughness and chloride permeability. Concrete was prepared using a drum mixer with a capacity of 0.25 m3.

4.3. Compression Strength Testing: For cubes 40 ton digital compressive testing machine was used for determine the compressive strength of hardened concrete as per the requirements of IS 516-1959. For cubes, before starting the test the weight of the sample was recorded. The plates of the machine were cleaned and the specimen was kept centrally between the two plates. Load was applied gradually on the specimen at a load rate of 5.2 kN/s up to failure. Once the sample was failed, the failure pattern was recorded and the compressive strength was calculated from the maximum load recorded in the test.

Table4: Compressive strength of concrete cubes

Mix Proportion	3days (MPa)	7days (MPa)	28days (MPa)	56days (MPa)
Mix 1	35.2	48.3	58.5	62.2
Mix 2	25.0	41.2	59	63.3
Mix 3	23.1	41.7	60.2	65.1
Mix 4	22.4	39.2	58.2	61.0
Mix 5	20.5	37.2	55.8	60.5
Mix 6	24.1	38.4	56.1	62.1
Mix 7	23.2	38.1	54.0	60.2
Mix 8	20.1	35.4	53.8	58.6

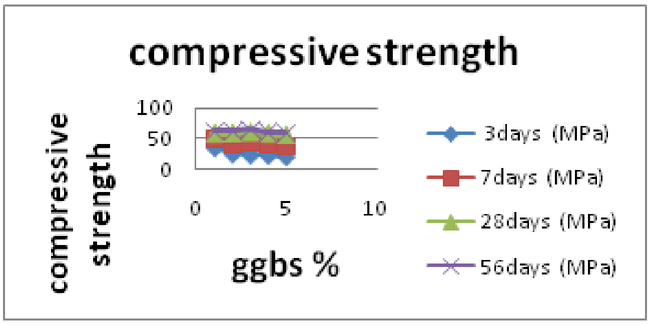

Fig1: Variation of compressive strength with increasing GGBS content

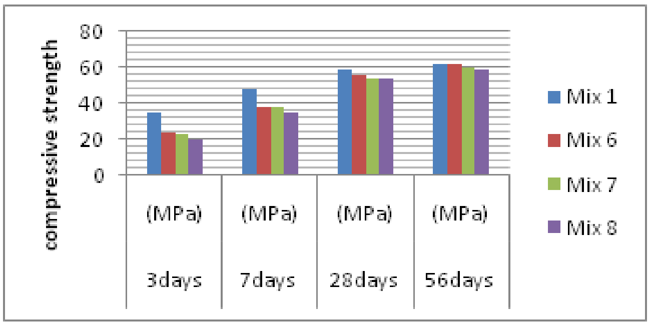

Fig2: Variation of compressive strength with combination of GGBS and flyash

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4.4 Tensile strength of concrete: For cylinders as per IS 5816-1999 , before starting the test the weight of the sample was recorded. The plates of the machine were cleaned and the specimen was kept centrally between the two plates. The load shall be applied without shock and increased continuously at a nominal rate within the range 1.2 N/ (mm2/min) to 2.4 N/ (mm2/min). Maintain the rate, once adjusted, until failure. The measured splitting tensile strength fc, of the specimen shall be calculated to the nearest 0.05 N/mm2 using the following formula:

$$F_s = 2P/ (\pi ld)$$

Table5: Tensile strength of concrete

Mix Proportion	3days (MPa)	7days (MPa)	28days (MPa)	56days (MPa)
Mix 1	2.8	3.8	4.4	5.2
Mix 2	2.5	3.4	4.6	5.6
Mix 3	2.5	3.6	4.8	5.9
Mix 4	2.2	3.4	4.5	5.4
Mix 5	2	3.1	4.1	4.9
Mix 6	2.4	3.6	4.5	5.6
Mix 7	2.2	3.3	4.4	3.9
Mix 8	1.8	2.9	3.9	4.8

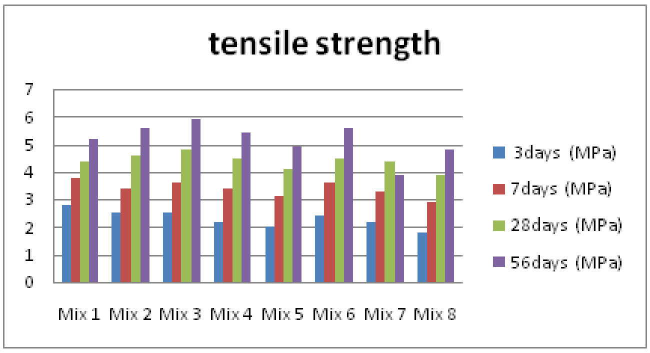

Fig3: Tensile strength of concrete

4.5. Rapid chloride permeability test: ASTM C 1202 prescribes the testing method for determining the chloride penetration resistance in of the concrete mixes. Two 4 by 8 standard cylinders were cast for each mix to execute this test. Test results for the 28-day cure chloride ion penetration tests can be seen in Table 7.

Table6: Rcpt test results 28-days

Mix Proportion	28days coulombs
Mix 1	1381
Mix 2	793
Mix 3	573
Mix 4	469
Mix 5	358
Mix 6	595
Mix 7	497
Mix 8	434

Table 7 – Permeability Classifications

Chloride Ion Penetrability Based on Charge Passed Charge Passed (coulombs) Chloride Ion Penetrability

>4,000	High
2,000-4,000	Moderate
1,000-2,000	Low
100-1,000	Very Low
<100	Negligible

One of the most important factors affecting the permeability of concrete is the internal pore structure, which in turn is dependent on the extent of hydration of the cementitious materials. The curing conditions and the age of the concrete thus largely determine the ease with which chloride ions can move into a concrete. From the test results it is observed that most concretes become significantly less permeable with increase in time. Therefore, it is important to specify the age at which the permeability is measured.

As per table 8 mix 1 that is normal concrete chloride permeability is low and other mix proportions of concrete chloride permeability is very low. It means that by replacing cement with ggbs and fly ash the chloride permeability decreases with increase in the ggbs content in the concrete mix.

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5. CONCLUSION

In this present study with the stipulated time and laboratory set up an afford has been taken to enlighten the use of so called pozzolanic material like ground granulated blast furnace slag, flyash concrete in accordance to their proficiency. It was concluded that,

- Use of GGBS as cement replacement increases consistency
- With the use of super plasticizer it possible to get a mix with low water to cement ratio to get the desired strength.
- The compressive strength of concrete increases with increase in ggbs content up to 40% replacement after that it decreases
- The compressive strength of normal concrete is almost equal to the strength of 30% GGBS and 10% flyash.
- Tensile strength of concrete also increases with the increase in ggbs content up to the 40% replacement.
- The reaction of the nano particle ggbs will be more than the micro particle.
- The chloride permeability of concrete decreases with increase in ggbs content and also with flyash content.

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