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EXPERIMENTAL BEHAVIOUR OF HIGH PERFORMANCE CONCRETE USING GGBS AND M-SAND

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Abstract - Concrete is the most widely used conventional construction material all over the world, because of its versatility, mould ability, durability, and resistance to fire and energy efficiency. However, concrete has less tensile strength, limited ductility and less resistance to cracking so it cannot be used as a structural material. Hence, in order to overcome these difficulties several new materials have been developed in the recent years. The objective of this experiment is to evaluate the ultimate behaviour of compressive and flexural strength of the concrete, by using GGBS (Ground granulated blast furnace slag) as partial replacement in cement and complete replacement of fine aggregate using M-sand (Manufactured sand) in High Performance Concrete. We are comparing the M25 grade concrete with M60 and M80 grade concrete, by replacing GGBS in the ratios of 0%, 25% and 50% in cement in order to improve its performance and chemical admixtures are used such as Fosroc and Glenium B-233.

Index Terms- High performance, GGBS, M-sand, Fly Ash, Micro Silica, Fosroc, Glenium B-233

I. Introduction

Concrete is a composite material composed of fine aggregate and coarse aggregate bonded together with fluid cement which hardens over time. Most use of the term "Concrete" refers to Portland cement concrete or to concretes made with other hydraulic cements, such as cement foundation. The cement reacts chemically with the water and other ingredients to form a hard matrix which binds all the materials together into a durable stone-like material that has many uses. Generally coarse gravel or crushed rocks used as coarse aggregate along with finer materials such as sand.Chemical admixtures are added to achieve varied properties. These ingredients may accelerate or slow down the rate at which the concrete hardens, and impart many other useful properties including increased tensile strength, entrainment of air, and/or water resistance. Reinforcement is often included in concrete. Concrete can be formulated with high compressive strength, but always has lower tensile strength. For this reason it is usually reinforced with materials that are strong in tension, often steel. The most conspicuous of these are fly ash, a by-product of coal-fired powerplants, ground granulated blast furnace slag, and silicafume, a by-product of industrial electric arc furnaces. The mix design depends on the type of structure being built, how the concrete is mixed and delivered, and how it is placed to form the structure.

A. Need for study

- The demand for river sand is increasing tremendously so M-sand is used as its alternative material.
- HPC have been used more widely in recent years for the construction of important concrete structures like high rise buildings, nuclear power plants, via ducts, bridges, etc.
- Due to the good quality of river sand for the need of construction the use of M-sand is increased.
- GGBS is the excellent binder to produced HPC.
- The chemical composition of GGBS contribution to the production of superior cement.

B. Objective

- The research aim is to study the effect of using GGBS and M-sand in high performance concrete.
- To conduct the experimental program to determine the ultimate compressive strength and flexural strength of HPC of grades M60 and M80 comparing these with that of M25 grade concrete.

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C. Significance of the study

a) GGBS

- Ensure higher durability of structure.
- Reduce the temperature rise and helps to avoid early-age thermal cracking workability.

b) M-sand

- It is well graded in the required proportion.
- It does not contain organic and soluble compound that affects the setting time and properties of cement, thus the required strength of the concrete can be maintained.

D. High Strength Concrete

High strength concrete is made by lowering thewater-cement (W/C) ratio to 0.35 or lower. Often silicafume is added to prevent the formation of free calcium hydroxide crystals in the cement matrix, which might reduce the strength at the cement-aggregate bond. Low W/C ratios and the use of silica fume make concrete mixes significantly less workable, which is particularly likely to be a problem in high strength concrete applications where dense rebar cages are likely to be used.

E. High Performance Concrete

High Performance Concrete (HPC) exceeds theproperties and constructability of normal concrete. Normal and special materials are used to make these specially designed concretes that must meet acombination of performance requirements. Magudeaswaran [1] and his fellow stated that, ACI defined that HPC as a concrete meeting some special combinations of performance and uniformity requirements which cannot be always achieved routinely using conventional constituents and normal mixing, placing, and curing practice. Vinayagam [2] stated that, to execute the HPC it requires lower water cement ratio and requires more cement content. The utility of HPC in prestress concrete construction makes greater span-depth ratio, early transfer of prestress and application of service loads. Low permeability characteristics of HPC minimize the risk of corrosion of steel and attack of aggressive chemicals. Sabale Vishal Dhondiram [3] and is fellow investigated that, HPC shows less internal micro cracking than nominal concrete for a given imposed axial strain. The Specific creep and the creep coefficient value are less in High-performance concrete (HPC) than in nominal strength axial strain. Sravani [4] and his fellow stated that, the main purpose of using HPC is, having improved durability minimize the life-cycle cost of structures. Due to these advantages, HPC are used in the construction of high rise buildings, nuclear power plants, viaducts, bridges, etc.

II. Materials used in the mix

A. M-Sand

Priyanka [5] and is fellows stated that, Manufactured sand is an alternative for river sand. Due to fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most part of the word. Another reason for use of M-Sand is its availability and transportation cost. Sheng-Dong HE [6] stated that, this sand can be crushed from hard granite rocks, it can be readily available at the nearby place, reducing the cost of transportation from far-off river sand bed. The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. A.Jayaraman [7] and his crew concluded that the combination of M-Sand and limestone replaces the combination of cement and river sand. The compressive strength of M-sand concrete is comparatively higher than that of River sand concrete with the same water cement ratio. Vijaya [8] and his fellow said that In M-sand, the process of attrition through Vertical Shaft Impact (VSI) and washing makes the crushed stone sand particles is well enough to be compared shape and surface texture of River sand. With well-designed screening system the required grading (Zone II) and fineness modulus of 2.4 to 3.1 can be achieved consistently in the case of manufactured sand. T.Shanmugapriya [9] stated that, the results indicate that there is an increase in compressive and flexural strength of HPC nearly 15-20% with increase of M-sand percentage. M.Adams Joe [10] and his fellows investigated that 50% replacement of river sand by M-Sand give higher result in strength and durability than the conventional concrete.

B. Ground Granulated Blast-Furnace Slag (GGBS)

Ground-granulated blast-furnace slag (GGBS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. Pithadiya and crew members [11] investigated that, nowadays the alkali activation in waste materials has become an important aspect of research area in many laboratories. So it is used to synthesize these materials in an inexpensive and ecological manner in construction materials. Maneeshkumar [12] and his fellow stated that, it is an important factor in order to find an alternative binder for cement which has low carbon footprint. GGBS exhibits cementitious as well as pozzolanic characteristics so it is quite right in choosing of fly ash and GGBS for concrete mix.

C. Fly Ash

JayeshkumarPitroda [13] and his fellows stated that, the Fly ash, also known as "Pulverized Fuel Ash" in the United Kingdom, is one of the residues generated by coal combustion, and is composed of the fine particles that are driven out of the boiler with the flue gases. Sizes of particle are 0.1 m-150 m. MudasirHussainPandit [14] stated that by using fly ash in the concrete generally increases the workability of the concrete, decreases bleeding in the concrete, decreases the hydration temperature and which reduces the permeability of the hardened concrete. Praveen [15] stated that, the Nano materials will improve the performance of the concrete as well while using, Nano Fly ash in the concrete leads to reduce the water demand and it will increase the strength in longer duration. Hence 50% of fly ash gives lesser strength but 30-40% of fly ash increases the strength of the concrete. Swapnil B. Cholekar [16] stated that the compressive strength and split tensile strength of the High Volume Fly Ash Concrete decreased with increase in percentage of foundry sand.

D. Micro Silica

TanveerHussain and Gopala Krishna Sastry p[17] stated that, the silica fume is the one of the waste materials that is being produced in tones of industrial waste per year in our count Silica fume, also known as micro silica, is an polymorph of silicon dioxide, silica. The bulk density of silica fume depends on the degreeof densification in the silo and varies from 130 to 600 kg/m^3.The maximum replacement level Micro silica is 7.5% and Nano silica is 2% for both M40 and M50 grade concrete. Verma Ajay, Chandak Rajeev and Yadav R.K [18] stated that the efficiency of silica fume is 3-5 times that of Ordinary Portland Cement and consequently concrete performance can be improved tremendously. Anil Kumar [19] and his crew concluded that Micro-silica reduce its initial strength but the strength gradually increases for larger time so ultimate strength is higher as compared to nominal concrete.

E. Reinforced Concrete

Reinforced concrete (RC) is a composite material in which concrete's relatively low tensile strength and ductility are counteracted by the inclusion of reinforcement having higher tensile strength and/or ductility. The reinforcement is usually, though not necessarily, steel reinforcing bars and is usually embedded passively in the concrete before the concrete sets. The size of the reinforcement bars we used is 12mm and 8mm, i.e. the spacing of the reinforcement bar is 100mm and the spacing of the stirrups is 150mm.

Fig. 2. Reinforcements

F. Fosroc Admixtures

Chemical admixtures are the ingredients in concrete other than Portland cement, water, and aggregate that is added to the mix immediately before or during mixing. Fosroc is a world-leading supplier of specialized construction chemicals. As leaders in admixture technology, Fosroc helps develop innovative concrete solutions for virtually any construction requirements Cost effective, project specific solutions, Extensive product portfolio, Easily applied systems, Proven technologies ensuring long term performance.

F. Glenium B-233

Glenium B233 is a light brown liquidadmixture of a new generation, based on modified polycarboxylic ether. Its relative density is 1.09 ± 0.09 with pH >6 and chloride ion <0.2% content. The product has been primarily developed for applications in high performance concrete where the highest durability and performance is required. The general use of this admixture, Production of Rheodynamic concrete, High performance concrete for durability, High early and ultimate strength concrete, High workability without segregation or bleeding, Precast & Pre-stressed concrete, Concrete containing Pozzolanas such as microsilica, GGBFS, PFA including high volume fly ash concrete.

III. Tests conducted for materials

A. Properties of cement

In order to use the best cement in construction, the properties of good cement must be investigated.

Table II. Physical Properties of Cement

Sl.No.	Characteristics	Value of Obtained Experimentally
1	Normal Consistency	29.33
2	Fineness of cement as Retained on 90 micron sieve	1.8
3	Initial Setting Time	165 min
	Final Setting Time	456 min
4	Specific Gravity	3.15
5	Soundness	0.9 mm

B. Properties of Fine aggregate

M-Sand is used as a fine aggregate and its physical properties are tested.

Table III. Physical Properties Of Fine Aggregates

Sl.No.	Test conducted	Test value
1	Sieve analysis	Zone–II confirming to IS 383:1970(RA:1997)
2	Specific gravity	2.66
3	Water absorption (%)	1.13
4	Loose bulk density(kg/m^3)	1513
5	Silt content (%)	2.1
6	Bulk age (%)	4.6

C. Properties of Coarse aggregate

Coarse aggregate are particles greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter.

Table IV. Physical properties of coarse aggregate.

Sl.No.	Test conducted	Test value
1	Sieve analysis	Zone–II confirming to IS 383:1970 (RA:1997)
2	Specific gravity	2.76
3	Water absorption(%)	0.54
4	Bulk age (%)	1431

IV. Preliminary test

A. Compressive Strength Test

It is the capacity of a material or structure towithstand loads. This test gives an idea about the characteristic of concrete. By this single test we can judge that whether concreting has been done properly or not. The size for the specimen of the cube is 15ommx150mmx150mm, we have done the casting and he curing period was taken is 14, 28 and 56 days for M25, M60, and M80 grades of concrete. The test results for the compression strength are listed below in the Table 5.

Fig. 3. Compressive Strength Test

Table V. Results For Compressive Strength Test

Sl. No	Grade	Percentage of replacement	Compressive Strength Test (N/mm^2)	
			14 days	28 days
1	M25	Nominal	20.2	27.35
		25%	22.5	31.59
		50%	21.6	29.19
2	M60	Nominal	59.90	63.82
		25%	61.12	68.62
		50%	60.54	67.59
3	M80	Nominal	78.90	81.44
		25%	79.60	84.22
		50%	81.20	80.89

B. Split Tensile Test

The tensile strength of the concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle in nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concede member may crack. The size of the cylinder is 300mmx150mm where it is also casted and cured for 14 and 28 days. The test results for the split tensile are given below in the Table 6.

Fig. 4. Split Tensile Test

Table VI. Results For Split Tensile Test

Sl. No.	Grade	Percentage of replacement	Split Tensile Strength Test (N/mm^2)M	
			14 days	28 days
1	M25	Nominal		
		25%	3.13	3.26

		50%	3.08	3.14
2	M60	Nominal	3.50	4.79
		25%	3.67	4.81
		50%	3.59	4.71
3	M80	Nominal	4.98	5.63
		25%	5.23	5.59
		50%	5.18	5.52

V. Experimental program

A. Flexural Test

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. Flexural is about 10 to 12 per cent of compressive strength depending on the type, size, and volumes of coarse aggregate used. Hence the size of the beam we used is 750x150x150mm since beam are also casted and cured for 14 and 28 days for the M25,M60 and M80 grades of concrete. Similarly for flexural strength we have taken two beams for each grade so totally for three different ratios for 14 and 28 days, we have casted 24 beams for the three different grades. The test result for the flexural strength is listed below in the Table 7.

Fig. 5. Flexural Strength Test

Table VII. Results For Flexural Strength Test

Sl. No.	Grade	Percentage of Replacement	Flexural Strength Test (N/mm^2)	
			14 days	28 days
1	M25	Nominal		
		25%	3.60	4.01
		50%	3.62	3.90
2	M60	Nominal	5.32	5.78
		25%	5.69	5.91
		50%	5.64	5.88
3	M80	Nominal	6.01	6.39

		25%	6.29	6.53
		50%	6.13	6.34

VI. Results and Discussions

The graph has been arrived for the M25, M60 and M80 grades concrete this shows the difference in their flexural strength of the specimens with various proportions (0%, 25% and 50%).

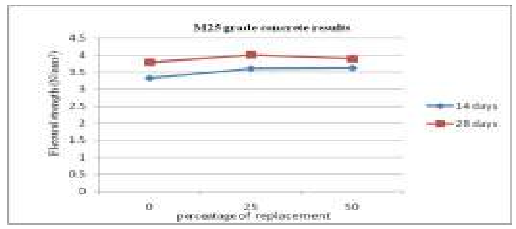

Fig. 6. M25 Grade Concrete Results

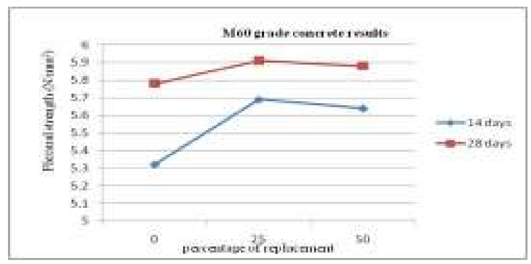

Fig. 7. M60 Grade Concrete Results

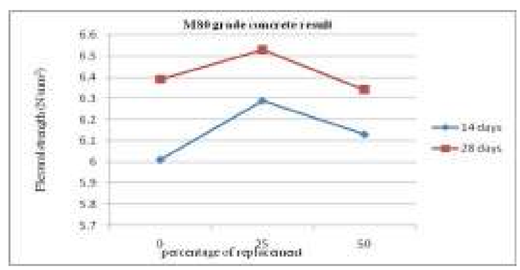

Fig. 8. M80 Grade Concrete Results

VII. Conclusion

Based on the experimental investigation the following conclusions are listed below:

- The optimum replacement level of GGBS in cement is 25%, because 25% replacement gives higher strength whereas the strength gradually reduces for the 50% of replacement proportion.
- In high performance concrete also 25% of replacement gives efficient strength.
- The chemical admixture Fosroc increases the strength in nominal mix. Whereas Glenium B233 increase the 2% of strength in high performance.

- Hence fly ash is used in high performance concrete because when it binds with GGBS it strength improves gradually whereas the fly ash will give an optimum result in 22-30%.
- Micro silica is used to fill the micro pores in the concrete. And it reduces the calcium hydroxide in cement which reduces the strength of the concrete.
- Using reinforcement in beams is another advantage because concrete is weak in tension, using of reinforcement will increase the strength of the beam and it is economic to use as well as ecofriendly for the environment.

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