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Development of Ultra High Performance Concrete using Microfine and GGBS

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Abstract: - Ultra high performance concrete is advanced level of concrete which possesses compressive strength in excess of 60 MPa. UHPC having good mechanical strength and durability. This provides long service life to the constructed structure with higher level of performance in terms of durability, performance, maintenance etc. In the present study the development of ultra high performance concrete by using Microfine and ground granulated blast furnace slag are used as a replacement of binding agent cement. The main aim is to develop Ultra high performance concrete which can give higher durability with greater performance and less maintenance of concrete during the service life of the structure. Ultra High Performance Concrete can also fulfill the requirement of architecture because it can be used for elevation design to make elevation more attractive and aesthetic along with that it also covers resistance against buckling behavior so that it will not buckle in case of Slender column.

Keywords:- *Mechanical Properties; Compressive Strength; Split Tensile Strength; Ground Granulated Blast Furnace Slag; Microfine etc.*

I. INTRODUCTION

The Ultra high performance concrete is the cementitious mixture which provides high mechanical strength with great performance. The world's population is getting increases very fast and there is requirements of efficient material in the construction are on the peak therefore the UHPC having potential to give best results in terms of both strength and performance. Research and development on new UHPC have been running from last 15 years and many researchers have given the solution for the proportion from which we can have high performance concrete related to strength and serviceability of concrete. This concrete can be used for Heavy Construction like Bridge, Dams, Flyover, Multi Storey Structure, Road pavement etc. Due to its performance it can create revolution in construction industry.

The construction material used to enhance the durability and workability of concrete are different types of fibers, micro fine, Ground granulated blast furnace slag etc. Concrete is the most popular and most consumed material in the construction industry and it has been used widely since the invention of the concrete and that also will be demanded in future.

At the time of invention of concrete nearby around 1960's the starting progress was very slow because the maximum compressive strength could achieve 15 MPa to 20 MPa only but now it has become very high like 80 Mpa to 100 MPa and even more. There is a increase in the strength along with the performance of the concrete and it's safe to use and have highly attracted the construction industry for concrete uses.

Because of the high costing the use of ultra high performance concrete is limited and the design codes which provide information regarding designing of ultra high performance concrete are also limited. To reduce the initial cost of ultra high performance concrete Microfine and Ground Granulated Blast Furnace Slag have been incorporated. Basically GGBS and Microfine are the waste by product of Steel Manufacture industry. These are capable enough to enhance the strength and durability of concrete.

For achieving higher ductility, small fraction of Steel fiber can be used. These waste materials having homogeneous structure and can provide homogeneity to the concrete.

II. MATERIALS

A. Materials

a. Ground Granulated Blast Furnace Slag (GGBS) and Microfine:

The nano material used in this project is Ground Granulated Blast Furnace Slag due to their rich mechanical strength and bonding strength along with Microfine for improving intermolecular bond between ingredients of concrete. GGBS and Microfine added as a replacement of Cement with certain percentage depending upon mix design.

- Physical Composition of GGBS:
  Color: White
  Specific Gravity: 2.92
  Bulk Density: 1060-1160 kg/m^3 (Loose) and 1260-1360 kg/m^3
  Fineness: > 350 m^2/kg

- Physical Composition of Microfine:
  Fineness: > 550 m^2/kg
  Compressive Strength: >15 (in N/mm^2 at 28 Days)
  Initial Setting Time: 150 minutes
  Final Setting Time: 180 minutes
  Grain Density: 2.92 kg/m^3

b. Cement:

The strength of concrete mainly depend upon the binding material cement. The Ultra high performance concrete must needed use of ordinary Portland cement of

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high quality. The quality of cement directly affects the strength of concrete and its durability. The physical and chemical property of the cement having predominant role in the performance of the concrete. Following are the key factors which are needed in the cement for achieving Ultra high performance concrete.

Cement Grade: Ordinary Portland Cement 53 – ACC
Conforming IS: 269
Minimum Compressive Strength (7 Days): 29.7 N/mm^2
Air Content in mortar: between 5 to 15%

The Portland cement of grade 53 was used in this study. All the experiments were performed as per IS 12269:2013. Various test performed on the cement like normal consistency, fineness, initial setting time and final setting time as per Indian standard.

c. Fine and Coarse Aggregate:

The distribution of aggregate normally creates uniformity in the concrete mix. The workability of concrete depends on the fine aggregate and coarse aggregate dispersion in the concrete. If the sand having sticky property then it will give the minimum compressive strength and workability to the concrete. The suitable range of fineness modulus for sand is 2.5 to 3.2 for Ultra high performance concrete. By crushing stones the coarse aggregate are obtained generally and having key role in the workability and compressive strength in the concrete. Many tests have been performed on coarse and fine aggregate to make it suitable for Ultra high performance concrete.

Aggregates having predominant role in strength and durability of concrete. The bifurcation of the aggregate are carried out by using Indian standard suggestions like if the particle size of the aggregate is less than 4.75 mm then it is categorized as fine aggregate and if the particle size are more than 4.75 mm then aggregates are categorized as coarse aggregate.

d. Admixture:

In this study, the strength enhancer and water amout reducer admixture is used. Perma Plast PC-405 admixture is used with the mixture. As per the suggestion or recommendation the minimum dose of admixture must be in the range of 0.2 to 1.5 % by weight of cement content. The dose of admixture should not be less or more than the range otherwise it would have diverse results in final observation.

III. METHODS AND EXPERIMENTAL DATA

A. Concrete Mix Design:

Mix design was done as per Indian Standard 10262:2009 with incorporation of GGBS and Microfine in certain % as a trial mixture.

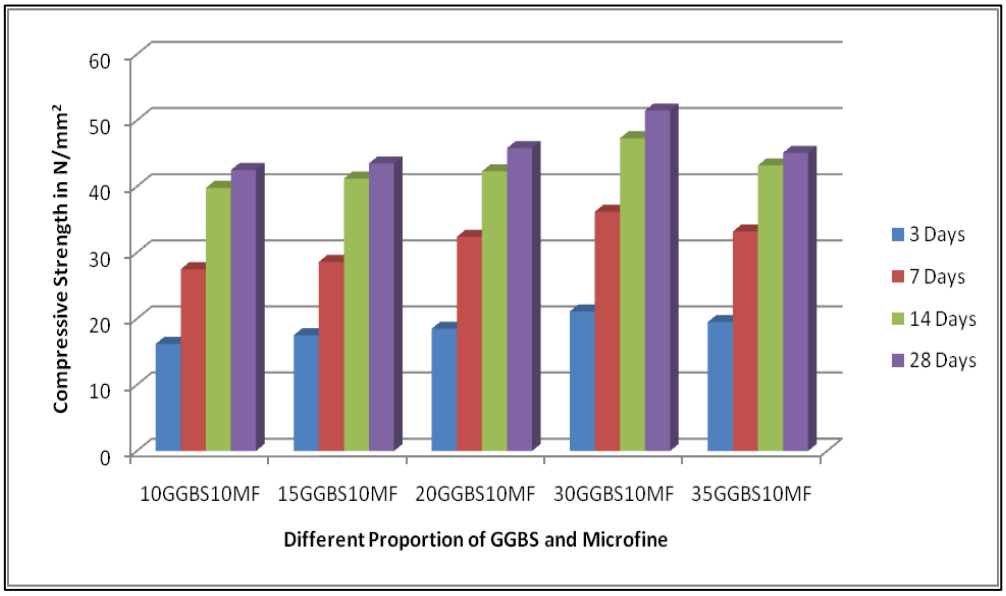
Testing:

a. Compressive Strength Test:

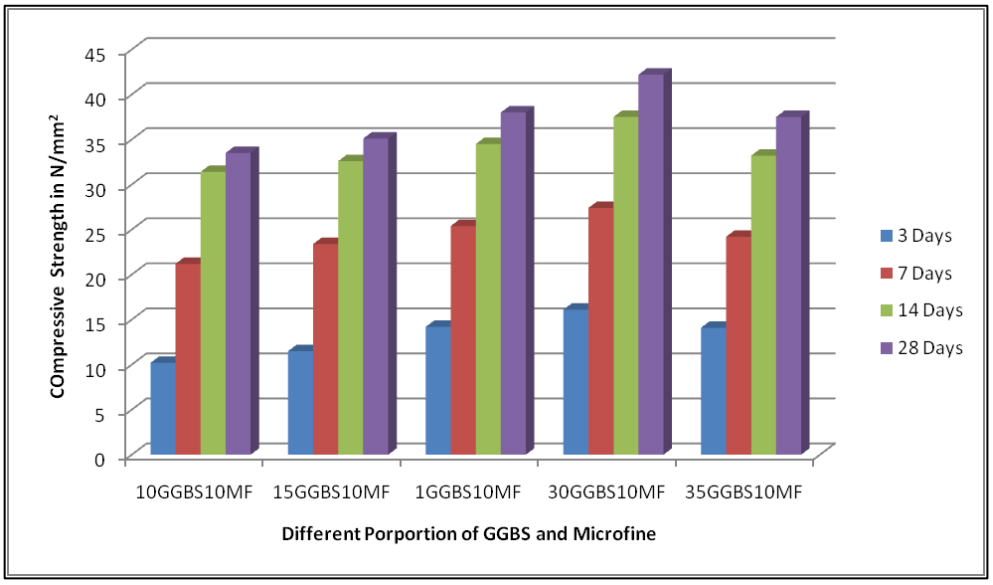
The Following data were observed as per mix design and proportion calculated.

Mix Design	W/C Ratio	GGBS (%)	Micro fine (%)	Compressive Strength in N/mm^2			
				3 days	7 days	14 days	28 days
M50	0.35	10	10	16.2	27.5	39.8	42.5
		15	10	17.5	28.6	41.2	43.5
		20	10	18.5	32.4	42.3	45.8
		30	10	21.1	36.2	47.3	51.5
		40	10	19.5	33.2	43.2	45.1
M40	0.35	10	10	10.2	21.2	31.4	33.5
		15	10	11.5	23.4	32.6	35.1
		20	10	14.2	25.4	34.5	38.0
		30	10	16.1	27.4	37.5	42.2
		40	10	14.1	24.2	33.2	37.5

Table 1: Compressive Strength Test Values of M50 and M40



Graph-1 Compressive Strength data comparison for Mix-50



Graph-2 Compressive Strength data comparison for Mix-40

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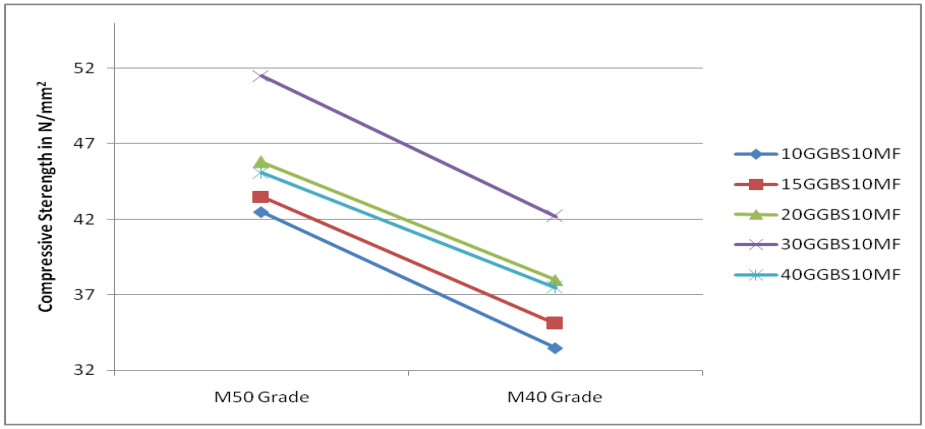

Graph-3 Comparative Graph for CS of Mix-40 and Mix-50

b. Split Tensile Strength Test:

This Test is performed to determine the split tensile strength of concrete. A Cylindrical mould is prepared having size 150 mm diameter and 300 mm length as per Indian Standard Specifications. After Preparing Specimen is prepared, the loads are applied on it across the vertical diameter. For this test various equipments and tools are used like grinding machine, compressive strength machine, capping fixture, PI tape, Ruler etc.

The Loads are applied as triaxial compression and it is applied until the tensile load failure point reaches.

Mix Proportion	Split Tensile Strength Value in (N/mm2)		
	7 Days	14 Days	28 Days
Mix 50 (W/C = 0.35) + GGBS (30%) and Microfine (10%)	5.40	7.00	7.75
Mix 40 (W/C = 0.35) + GGBS (30%) and Microfine (10%)	4.12	5.63	6.45

Table 2: Split Tensile Strength on different trials

c. Flexural Strength Test:

Flexural strength test is used to find out tensile property of the concrete. The core concept behind this test is to determine how much load the beam can resist under bending. For performing this test, specimen is prepared having size 150 mm x 150 mm and length 700 mm. This mould is poured with concrete mix and further this specimen is placed to perform three point load experiment. The loading conditions are applied at one third and two third by the total length of the specimen. Tests are always performed after the minimum curing required as per the Indian Standard.

Mix Proportion	Flexural Tensile Strength Value in (N/mm^2)		
	7 Days	14 Days	28 Days
Mix-50 (W/C = 0.35) + GGBS (30%) and Microfine (10%)	5.92	7.75	9.40
Mix-40 (W/C = 0.35) + GGBS (30%) and Microfine (10%)	4.55	6.24	6.92

Table 3: Flexural Tensile Strength on different trial

d. Rebound Hammer test:

Rebound hammer test comes under non-destructive test in which compressive strength of the concrete is identified without any dismantle of concrete.

This test is used to assess the durability workability and consistency of concrete. it is the one of the convenient method used to determine the compressive strength of concrete without any physical destruction. In this experiment instrument is used in which a plunger is fitted and it is connected to a spring that used to control the mass. After that marking is done on the surface and the minimum horizontal distance between two marks must be 25 mm. From the end of the surface it must be 50 mm. we need to impose total 10 numbers of marking on the surface of concrete to identify the compressive strength by using by performing rebound hammer test.

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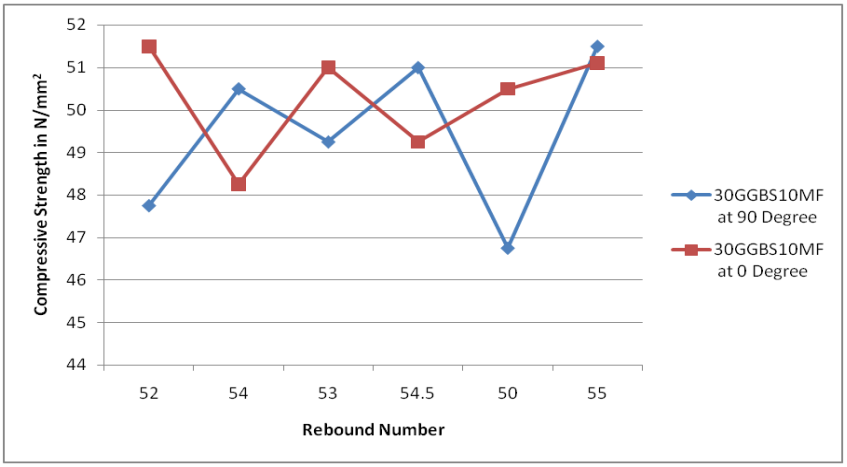

Graph-4 Comparison of CS at 0 and 90 degree.

e. Ultrasonic Pulse Velocity Test*:*

The ultrasonic pulse velocity test is also comes under non destructive test. This test is used to determine the quality of concrete in terms of uniformity and consistency of mix. In this experiment, Ultrasonic waves passes through the concrete specimen and the time taken by the Ultrasonic waves to pass that specimen is noted. If the time consumed by the ultrasonic wave is more that means there is something which is uniform and well organize structure. If the time taken by the wave is less that means there is something which is not well organized or disturbed arrangement of mixture ingredient. Further, there is no need to disintegrate the structure to determine these values.

Spot No.	Pulse Velocity (Km/Sec)		Concrete Quality (Grading)
	Direct Method	Semi Direct Method	
1	4.05	4.00	Good
2	4.25	3.95	
3	3.80	3.91	
4	4.17	4.20	
5	4.3	3.99	

Table 4: Pulse Velocity test Observations

IV. CONCLUSIONS

By adding GGBS and Microfine to achieve UHPC, the following conclusions were made as per expectations and observation received.

- GGBS and Microfine both are capable to enhance the Physical property of concrete like compressive strength, Ductility and performance of concrete under service period.
- The Compressive Strength found 43.5 N/mm ^{2} and 52.75 N/mm ^{2} after 28 days for Mix-40 and Mix-50.
- By considering economic point of view, the UHPC is 15.5% Cost effective than conventional concrete due to using Industrial waste by product.
- The Best results found when we add 30% GGBS and 10% Microfine as a replacement of cement.
- The Split and Flexural tensile strength were maximum when 30% GGBS and 10% Microfine is added.
- The Water Cement ratio is 0.25 for getting best result under this proportion.
- Ultrasonic Pulse Velocity and Rebound hammer test results were also up to the mark as per expectation and categorized as good.
- UHPC is also capable to protect itself from corrosion and acid Attack..

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