Characteristics of GGBS as an Alternate Material in Conventional Concrete

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Abstract: Utilization of alternate cementation materials leads to several possible improvements in the concrete composites also as well as in the overall economy of construction projects. This requirement is drawn the attention of investigators to explore new replacements of ingredients of concrete. Cement with GGBS replacement has emerged as a major alternative to conventional concrete and has rapidly drawn the concrete industry attention due to its cement savings, energy savings, cost savings, environmental and socio-economic benefits. The present paper is an effort to quantify the strength of ground granulated blast furnace slag (GGBS) at various replacement levels and evaluate its efficiencies with respect to concrete. This research evaluates the strength and strength efficiency factors of hardened concrete, by partially replacing cement by various percentages of ground granulated blast furnace slag for M25 grade of concrete at various ages. From the study, it can be concluded that, since the grain size of GGBS is less than that of ordinary Portland cement, its strength at early ages is low & will continue to gain strength up to 20% more than cement over a period of 28 days curing and also the workability of concrete is effective up to an addition of 40 % replacement of GGBS with concrete. The optimum GGBS replacement as cementation material is characterized by high compressive strength, low heat of hydration, resistance to chemical attack, better workability, good durability and cost-effectiveness.

Key words: **GGBS (slag cement), Workability, Compressive strength, Tensile strength, Flexural strength**.

I.INTRODUCTION

Blast furnace slag is a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace and the resulting molten slag floats above the molten iron at a temperature of about1500 C to 1600 C. The molten slag has a composition of 10% to 20% silicon dioxide (SiO_2) and approximately 40% CaO, which is close to the chemical composition of Portland cement. After the molten iron is tapped off, the remaining molten slag which mainly consists of siliceous and aluminous residues is then rapidly water- quenched resulting in the formation of a glassy granulate, this glassy granulate is dried and ground to the required size which is known as ground granulated blast furnace slag (GGBS).

The replacement of Portland cement with GGBS will lead to a significant reduction of carbon dioxide gas emission and can be used to replace as much as up to 80% of ordinary Portland cement when used in concrete mix. GGBS has better water non permeability characteristics and also as well as improved resistance to corrosion and sulphate attack as a result, the service life of a structure is enhanced which can reduce the maintenance cost. The setting time of concrete is influenced by many factors in which the two major factors are temperature and water/cement ratio. With GGBS as an alternate material in concrete, the setting time can be slightly extended, An extended setting time is Very much advantageous in concrete and will remain workable for longer periods which is useful in warm weather conditions.

Replacement levels for GGBS can vary from 30% to 85% in which typical 40 to 50% is used in most of the instances. For ground concrete structures which requires higher early-age strength, the replacement ratio would usually be 20 to 30% whereas for underground concrete structures with average strength requirement, the replacement ratio would usually vary by 30 to 50%. In mass concrete or concrete structures with strict temperature rise requirement, replacement ratio would usually be vary from 50 to 65% & for the special concrete structures with higher requirement in durability i.e, corrosion resistance for marine structures & for sewage treatment plants, the replacement ratio would usually be 50 to 70% by weigh of cement material. A typical combination of 50% GGBS with 50% Portland cement is analysed for any part of the concrete structures where in which greater the percentage of GGBS greater will be the effect on concrete properties. With the inclusion of GGBS in cement, setting time can be extended up to 30 minutes & its effect will be more pronounced at high levels at low temperatures.

Applications Of GGBS-
- ✓ Better workability, placing and compaction of concrete material.
- ✓ Lower early age temperature rise which reduce the risk of thermal cracking in large pours.
- ✓ Elimination of the risk due to internal reactions in concrete constituents.
- ✓ High resistance to chloride ingress which reduce the risk of reinforcement corrosion.
- ✓ High resistance to attack by sulphate and other chemicals.

II.REVIEW OF LITERATURE

Ground Granulated Blast Furnace Slag (GGBS) is a by-product of Iron industry and which is obtained during the manufacture of iron. The molten slag is a secondary product of sintering the raw materials and is quenched under high pressure of water jets which results as GGBS. This is a very fine powder with a specific surface area of 400-600m^2/kg with a bulk density of 1200 Kg/m^3.With the partial replacement of cement by its weight for strength and durability properties it has been noticed that there is an increase in both compressive & flexural strength development for the first three days of hydration in concrete containing 40-65% of GGBS as an alternate material [1].

The properties of GGBS & its reaction mechanism has a considerable effect on strength and durability properties of concrete in which the optimum compressive strength is obtained with 20% replacement and 10% for flexural strength for an M25 grade concrete which has been tested for 3,7 & 28 days also the partial replacement of GGBS was varied from 50-80% containing W/C ratio of 0.4 in which with the incorporation of slag at 50% and above replacement level will cause reduction in its strength [2].
The effect of curing procedure on the compressive strength with development of cement mortar and concrete incorporating ground slag with a specific surface area between 4000 cm^2/g and 6000 cm^2/g would significantly improve the performance of GGBS concrete material, with the specifications, production method and degree of effectiveness of some industrial by-products such as GGBS, Silica Fume and PFA as cement replacement to achieve high performance and sustainable concrete which can lead not only to improving the performance of the concrete but also to the reduction of CO_2 by reducing its after affects [3].

The study focuses on the autogenous deformation & evolution of concrete characterized by different percentages of slag (0 and 42% of the binder mass) under free and restraint conditions by means of the TSTM device (Temperature Stress Testing Machine) and also study involves in the effects of mineral admixtures on water permeability and compressive strength of concretes containing silica fume (SF) and fly ash (FA) in which the results were compared with ordinary Portland cement concrete without admixtures. The optimum cement replacement by FA was up to 10%. The strength and permeability of concrete containing silica fume, fly ash and high slag cement could be beneficial in the utilization of these waste materials in concrete work especially in terms of durability [4].

Potentiality of GGBS is activated by cement and lime for stabilization purposes which is mixed initially in the soil with varying proportions & the results showed that GGBS activated by cement and lime would be effective in reducing the leachability of contaminants in contaminated soils. Also the studies has shown that the concrete specimens tested cannot adequately address the durability threat to all parts of wastewater infrastructure over a significant life span due to the extraordinarily harsh nature and is characterized by high strength, lower heat of hydration and resistance to chemical corrosion[5].

With the same content of cementitious material (the total weight of Portland cement plus GGBS), similar 28 day strengths to Portland cement will normally be achieved when using up to 50% GGBS. At higher GGBS percentages the cementitious content may need to be increased to achieve equivalent 28 day strength. GGBS concrete gains strength more steadily than equivalent concrete made with Portland cement. For the same 28 day strength, a GGBS concrete will have lower strength at early ages but its long term strength will be greater, the reduction in early strength will be most noticeable at high GGBS levels and low temperatures. Typically a Portland cement concrete will achieve about 75 percent of its 28 day strength at seven days, with a small increase of five to ten percent between 28 and 90 days. By comparison, a 50 % GGBS concrete will typically achieve about 45 to 55 % of its 28 day strength at seven days, with a gain of between 10 and 20 % from 28 to 90 days. At 70 % GGBS, the seven day strength would be typically around 40 to 50 % of the 28 day strength, with a continued strength gain of 15 to 30 % from 28 to 90 days. Under normal circumstances, the striking times for concretes containing up to 50 % GGBS, do not increase sufficiently to significantly affect the construction programme. However, concretes with higher levels of GGBS will not always achieve sufficient strength after one day to allow removal of vertical formwork, particularly at lower temperatures, lower cementitious contents and in thinner sections [6].

The maximum strength was observed for 20µm particle size and lesser strengths (for all days of testing) are observed for 250µm particle size. For 20% replacement, the strength at 7 days, for 20µm particle size is 18.2 MPa, and the corresponding percentage increase is 25% when compared with control mix. Similarly for 250µm particle size, the strength is less than control mix, and the percentage decrease in strength is 13%.At 14 and 21 days, the percentage increase in strength for 20µm particle size, when compared with control mix is 17% and 24% respectively, whereas for 250m particle size there is an decrease in strength equal to 28% and 7%. At 28 days of testing, the percentage increase in strength for10%, 20%, 30% and 40% replacements of 20µm particle size is 5%, 12%, 7% and 1% respectively when compared with control mix. The optimum compressive strength is obtained for 20µm size of GGBS particles and effective dosage is noticed at 20% replacement level of cement with GGBS [7].
In very cold weather and for small or thin concrete elements, reducing to 30% GGBS may be required to allow formwork to be struck in accordance with traditional practice. For larger concrete elements, irrespective of replacement rates of GGBS, cold weather will not impact on the standard practice - once the standard cold weather concrete precautions are taken, such as covering with plastic sheeting and insulation where there is a danger of temperatures falling below 5 degrees,(this practice is to protect against surface frost damage). Finally, for concrete using higher percentages of GGBS it will generally be much stronger than concrete that has not used a blend of GGBS [8].

III.MATERIALS & METHODOLOGY

1. Materials

a. Ordinary Portland Cement of 53 Grade.
b. Aggregates of pertaining Sieve size (<20mm) as per IS standards.
c. River Sand of pertaining Sieve size (<4.75mm) as per IS standards.
d. Ground Granulated Blast furnace Slag (GGBS) of pertaining Sieve size (90 µ) as an alternate material as per IS standards.

Table:1 Typical physical properties of GGBS

Si no	Physical properties	
1	Colour	off white
2	Specific gravity	2.9
3	Bulk density	1200 Kg/m^3
4	Fineness	350 m^2/kg

Table:2 Typical chemical composition of GGBS

Si no	Chemical composition	
1	Calcium oxide	40%
2	Silica	35%
3	Alumina	13%
4	Magnesia	8%

2. Methodology

Preliminary tests were conducted on the concrete materials as per IS standards & specifications for its physical & engineering properties, cubes were casted in the standard metallic moulds & vibrated to obtain the required sample size of specimen. The moulds were cleaned initially and oiled on all the sides before concrete sample is poured in to it. Thoroughly mixed concrete is poured into the moulds in three equal layers and compacted using vibrating table for a small period of 5 minutes. The excess concrete is removed out of the mould using trowel and the top surface is finished with smooth surface. After 24 hours the samples were demoulded and put in curing tank for the respective periods of 7, 14, 21 and 28 days a set of 5 samples were prepared for each stage of curing. The temperature of curing tank was maintained about 25 degree during the analysis of compressive strength were tabulated.

The main aim of the methodology is to-

- To calculate the compressive strength of M25 grade plain concrete by laboratory experiments as per IS specifications.
- To calculate the Split tensile strength of M25 grade plain concrete by laboratory experiments as per IS specifications.
- To calculate the Flexural strength of M25 grade plain concrete by laboratory experiments as per IS specifications.
- To find the percentage of cement replaced in concrete with Ground Granulated Blast Furnace Slag (GGBS) as an admixture that gives maximum characteristic compressive strength for a given concrete material.

Tests (physical properties) conducted on Concrete materials

➢ **Test on cement**

- Fineness of cement.

- Normal Consistency of cement.
- Soundness test.
- Specific gravity.
- Initial setting time of cement.
- Final setting time of cement.

TABLE-3 Test on Cement

Si no	Test	Method of test	Average Result	Permissible value
1	Fineness of cement	IS 269-1976	7%	Max 10%
2	Normal consistency	IS:4031-Pt-4	29%	26 to 33%
3	Soundness	IS:4031-Pt-3	7 mm	< 10mm
4	Specific gravity	IS:2720-Pt-3	3.1	3.12to 3.19
5	Initial setting time	IS 4031-1968	38 mins	Min 30 mins
6	Final setting time	IS 4031-1968	300 mins	Max 600 mins

- **Tests on Coarse aggregates**
- Sieve analysis.
- Specific gravity.
- Water absorption.
- Aggregate shape test.
- Aggregate crushing test.
- Aggregate impact test.
- Los Angeles abrasion test.

TABLE-4 Test on coarse aggregates

Si no	Test	Method of test	Average Result	Permissible value
1	Sieve analysis	IS:2720-Pt-4	Fineness modulus = 2.7	2.3 to 3.1
2	Specific gravity	IS:2386-Pt-3	Bulk specific gravity = 2.7 Apparent specific gravity = 2.7	2.5 to 3.2
3	Water absorption	IS:2386-Pt-3	1.0	<2%
4	Aggregate shape test	IS 2386-1 (1963)	22%	<30%
	Flakiness index			
	Elongation index		21%	
5	Aggregate crushing test	IS:2386-Pt-4	18%	<30%
6	Aggregate impact test	IS:2386-Pt-4	17%	<24%
7	Los Angeles abrasion test	IS: 2386- (Part IV) – 1963	23%	<30%

- **Test on fine aggregates – River sand (Size <4.75mm)**
- Specific gravity and Water absorption test.

TABLE-5 Test on fine aggregates (River sand)

Si no	Test	Method of test	Average Result	Permissible value
1	Specific gravity	IS:2720-Pt-3	Bulk specific gravity = 2.60 Apparent specific gravity = 2.48	2.53 to 2.67
2	Water absorption	IS:2386-Pt-3	1.0	<2%

- **Test on Ground Granulated Blast Furnace Slag GGBS (Size 90 µ)**
- Specific gravity and Water absorption test.

TABLE-6 Test on Ground Granulated Blast Furnace Slag (GGBS)

Si no	Test	Method of test	Average Result	Permissible value
1	Specific gravity	IS:2720-Pt-3	Bulk specific gravity = 2.90 Apparent specific gravity = 2.8	--
2	Water absorption	IS:2386-Pt-3	0.14%	--

3. **Tests (Engineering properties) conducted on Plain Concrete**

- **Test on Plain concrete**
- Slump test.
- Compaction factor.
- Vee Bee consistometer.
- Compressive strength of concrete.
- Split tensile strength of concrete.
- Flexural strength of concrete.

TABLE-7 Test on Plain concrete

Si no	Test	Method of test	Average Result	Permissible value
1	Slump test	IS-7320-1974	True slump for 0.5 water cement ratio	--
2	Compaction factor	IS-1199-1959	0.9	--
3	Vee Bee consistometer	IS-10510-1983	20 seconds	--
4	Compressive strength of plain concrete (7 days)	IS 1489-1991	18.44 N/mm^2	Min 17 N/mm^2
5	Compressive strength of plain concrete (14 days)	IS 1489-1991	22.0 N/mm^2	Min 22 N/mm^2
6	Compressive strength of plain concrete (21 days)	IS 1489-1991	23.0 N/mm^2	Min 23.5 N/mm^2
7	Compressive strength of plain concrete (28 days)	IS 1489-1991	25.3 N/mm^2	Min 25 N/mm^2
8	Split tensile strength of plain concrete (7 days)	IS 5816-1976	4.9 N/mm^2	--
9	Split tensile strength of plain concrete (28 days)	IS 5816-1976	5.47 N/mm^2	--
10	Flexural strength of plain concrete (7 days)	IS: 516-1959	5.28 N/mm^2	--
11	Flexural strength of plain concrete (28 days)	IS: 516-1959	5.36 N/mm^2	--

4. **Tests (Engineering properties) conducted on Concrete with partial replacement of GGBS**

- **Test on concrete**
- Slump test.
- Compaction factor.
- Vee Bee consistometer.
- Compressive strength of concrete.

TABLE-8 Test on concrete with partial replacement of GGBS

Si no	Test	Method of test	Average Result
1	Slump test	IS-7320-1974	True slump for 0.5 water cement ratio
2	Compaction factor	IS-1199-1959	0.9
3	Vee Bee consistometer	IS-10510-1983	25 seconds

4	Compressive strength of concrete with M sand (7 days)	IS 1489-1991	16.2 N/mm^2
5	Compressive strength of concrete with M sand (14 days)	IS 1489-1991	19.3 N/mm^2
6	Compressive strength of plain concrete (21 days)	IS 1489-1991	22.5 N/mm^2
7	Compressive strength of concrete with M sand(28 days)	IS 1489-1991	25.6 N/mm^2

5. EXPERIMENTAL DESIGN

MIX DESIGN

Volumetric batching is done for the material mix to analyse the amount of quantity required for casting each cube specimen considering the design mix as M25 grade (cement: fine aggregate: coarse aggregate) is 1: 1: 2 as per IS 383-1970 & IS 456-2000 specifications. The aggregates with cement mix are varied up to 35% of porosity by varying the materials having minimal or zero number of fine aggregates & is mixed with cement for a water cement ratio of 0.5 to cast the moulds for analysing the compressive strength of 7, 14, 21 & 28 days strength for an average of 5 specimens.

The percentage of Ground Granulated Blast Furnace Slag (GGBS) is varied from 0 % to 40% in its weight & is added to the concrete mix as an admixture & is tested for its compressive strength for varying 7, 14, 21 & 28 days strength. The obtained results are tabulated as a comparison of characteristic strength between plain concrete mix & GGBS as an admixture for the concrete mix of M25 grade for an average of 5 specimens.

IV.RESULTS & DISCUSSION

Relation between characteristic compressive strength for the plain concrete mix for 7, 14, 21 & 28 days

With the volumetric batching for the plain concrete material mix is done to analyse the amount of quantity required for casting each cube specimen considering the design mix as M25 grade (cement: fine aggregate: coarse aggregate) is 1: 1: 2 as per IS 383-1970 & IS 456-2000 specifications & tested for its strength for 7, 14, 21 & 28 days strength in which the compressive strength by testing under compressive testing machine has given an average values of 22.0 N/mm^2 & 25.3 N/mm^2 for 14 & 28 days which are more than permissible limits as per specifications respectively.

TABLE-9: Comparison of compressive strength in concrete specimens for 7, 14, 21 & 28 days in N/mm^2

Si no	Average strength at 7 days (N/mm^2)	Average strength at 14 days (N/mm^2)	Average strength at 21 days (N/mm^2)	Average strength at 28 days (N/mm^2)
1	18.4	21.1	22.6	24.38
2	18.55	21.9	23.0	26.98
3	18.54	22.0	23.0	25.50
4	18.10	21.6	22.7	24.40
5	18.60	23.4	22.8	25.45

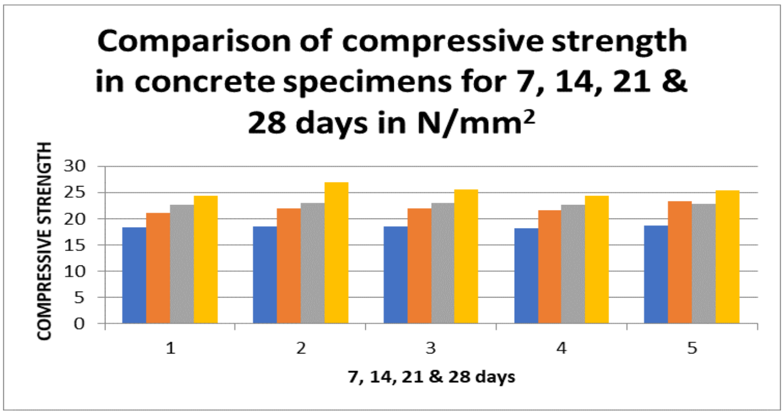

Fig-1: Comparison between compressive strength of plain cement concrete for 7, 14, 21 & 28 days

TABLE-10: Comparison of Split tensile strength in plain concrete specimens for 7 & 28 days in N/mm^2

Si no	Average strength at 7 days (N/mm^2)	Average strength at 28 days (N/mm^2)
1	4.95	5.36
2	5.23	5.43
3	4.98	5.2
4	4.6	5.67
5	5.2	5.8

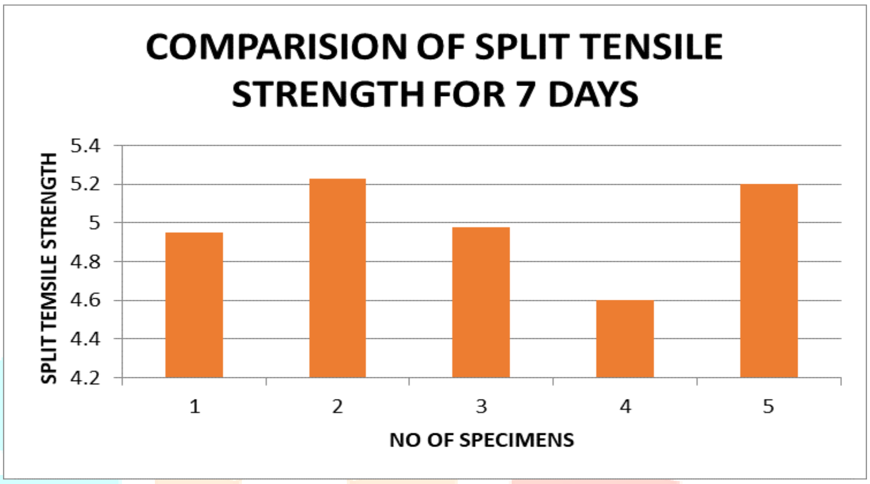

Fig-2: Comparison between Split tensile strength of plain cement concrete for 7 days

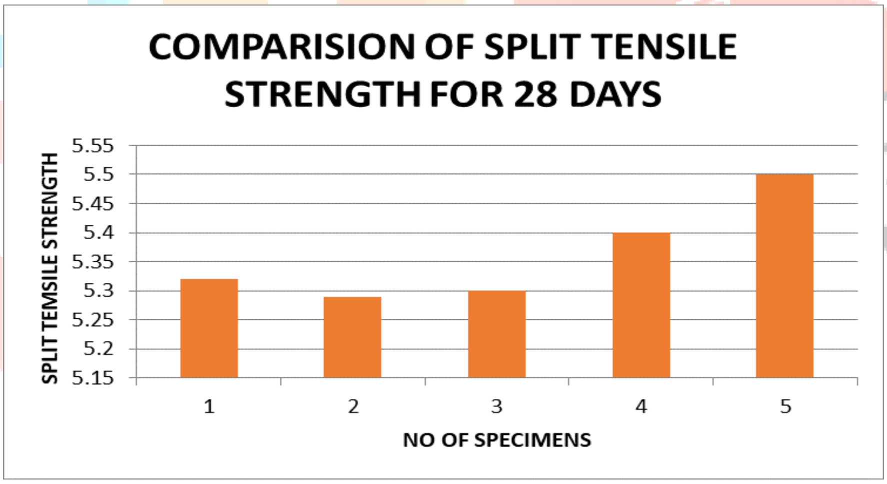

Fig-3: Comparison between Split tensile strength of plain cement concrete for 28 days

TABLE-11: Comparison of Flexural strength in plain concrete specimens for 7 & 28 days in N/mm^2

Si no	Average strength at 7 days (N/mm^2)	Average strength at 28 days (N/mm^2)
1	5.15	5.32
2	5.23	5.29
3	5.19	5.3
4	5.25	5.4
5	5.62	5.5

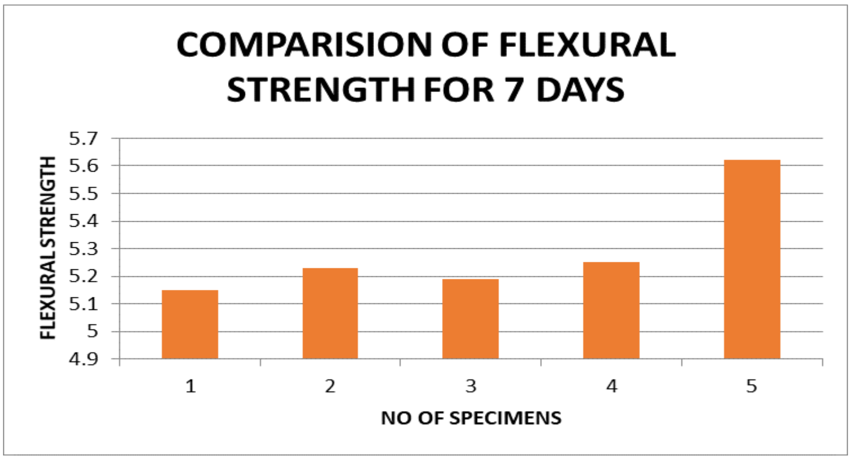

Fig-4: Comparison between Flexural strength of plain cement concrete for 7 days

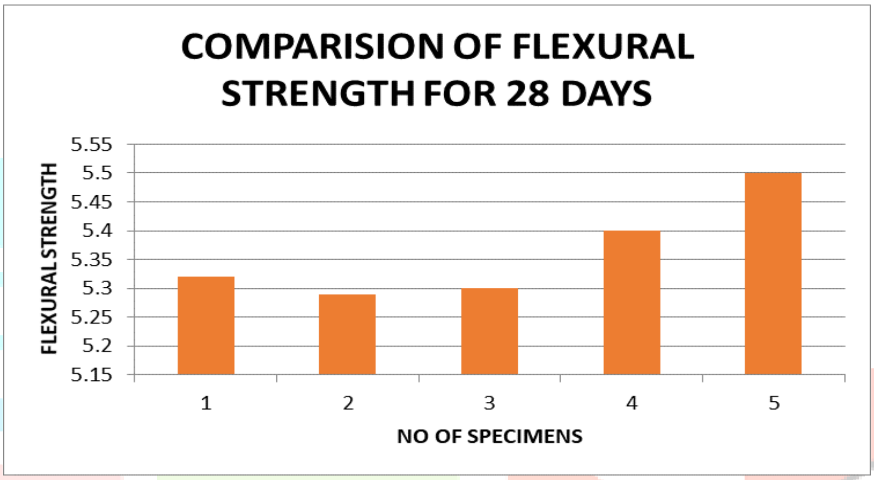

Fig-5: Comparison between Flexural strength of plain cement concrete for 28 days

Relation between characteristic compressive strength for the concrete mix & GGBS as an admixture for 7, 14, 21 & 28 days

With the inclusion of Manufactured sand in varied proportions the strength of concrete gradually increases up to a certain limit but the gradually decreases. By the experimental analysis with the inclusion of GGBS up to 40% by its weight as a filler material will lead to increase in the initial compressive strength of the concrete blocks. There is 10% to 20% increase in initial compressive strength for 7 days & also 10% to 15% increase in initial compressive strength for 28 days where as initial & final characteristic compressive strength gradually decreases from 40% increase in GGBS in the concrete mix.

TABLE-12: Comparison of compressive strength for various specimens with varying % in GGBS for 7, 14, 21 & 28 days in N/mm^2

Si no	% OF GGBS	Average strength at 7 days (N/mm^2)	Average strength at 14 days (N/mm^2)	Average strength at 21 days (N/mm^2)	Average strength at 28 days (N/mm^2)
1	**0**	18.44	22	23.2	25.3
2	**10**	14.3	16.0	20.3	24.0
3	**20**	15.1	17.1	23.2	25.7
4	**30**	15.9	17.8	24.3	26.4
5	**40**	14.3	16.2	21.5	24.3

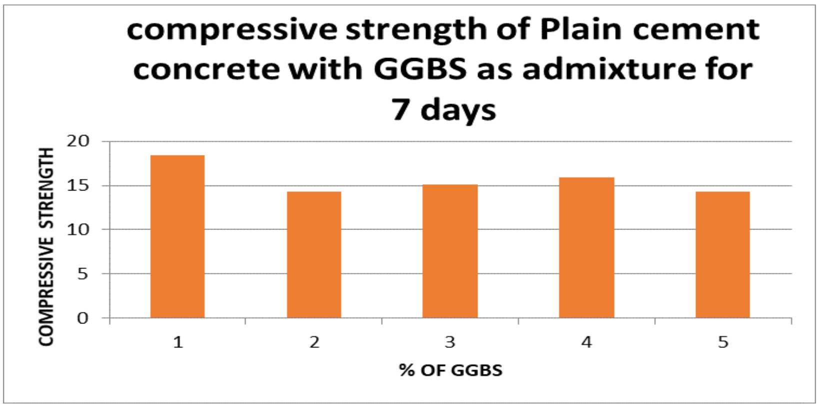

Fig-6: Comparison between compressive strength of plain cement concrete with GGBS as admixture for 7 days

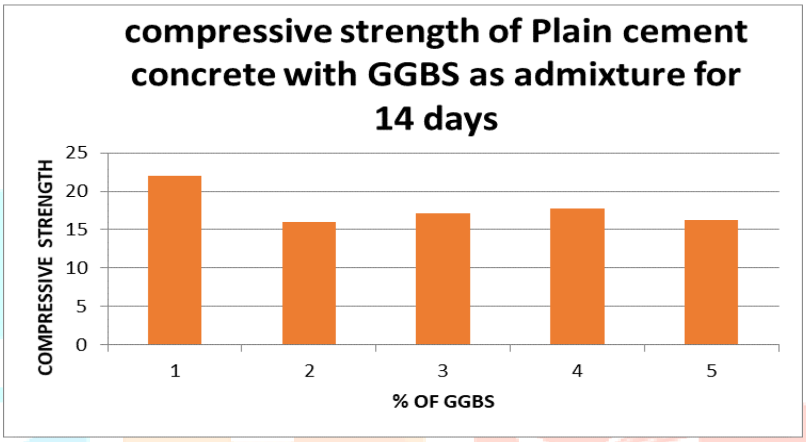

Fig-7: Comparison between compressive strength of plain cement concrete with GGBS as admixture for 14 days

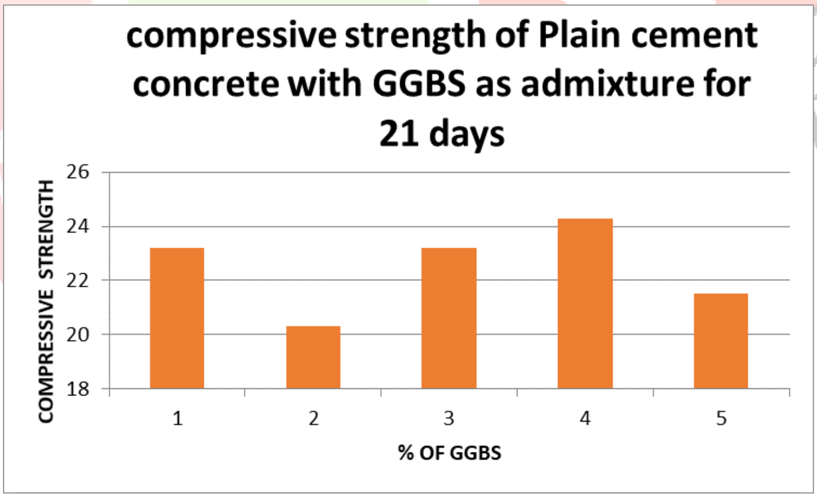

Fig-8: Comparison between compressive strength of plain cement concrete with GGBS as admixture for 21 days

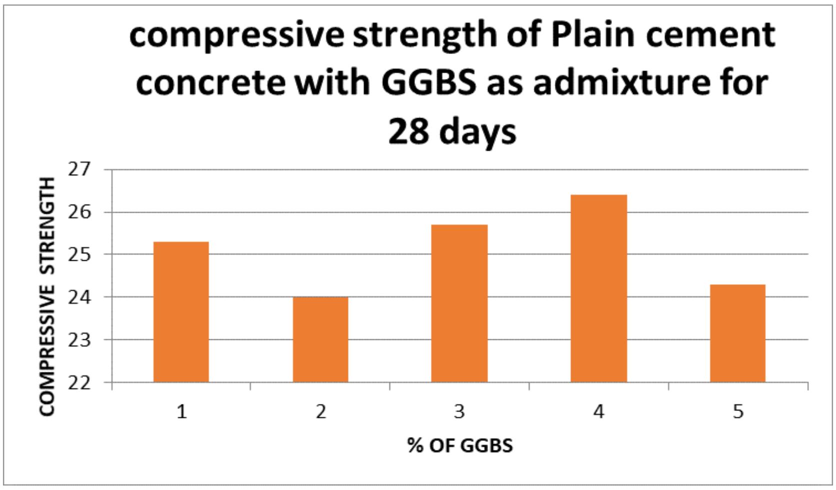

Fig-9: Comparison between compressive strength of plain cement concrete with GGBS as admixture for 28 days

V.CONCLUSION

1. Mechanical behavior of concrete cubes prepared without chemical admixtures were studied for Compressive, Split tensile & Flexural strength test with curing time of 7 days, 14 days, 21 days and 28 days which shows characteristic increase in its strength behavior.
2. It can be noticed that 10% replacement of cement with GGBS in mild condition are showing an increase in compressive strength for 28 days & with up to 40%% replacement of cement with GGBS in mild condition are showing a variation in its compressive strength.
3. With the presence of GGBS as an admixture, As the particle size decreases the strength increases for all replacements of cement with GGBS and has been concluded that it can be very effective in assuring good cohesiveness between mortar and concrete.
4. From the above study, it can be concluded that the GGBS can be used as a replacement material in cement and up to 40% replacement will give an excellent results both in strength & quality aspects.
5. Also with increase in percentage of GGBS up to 40% will lead to the improvement in properties related to durability & workability of concrete.
6. The mix prepared with 20% replacement of fine aggregate by GGBS is most economical and gives high characteristic strength when compared to conventional mix.

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Bibilography

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