Influence of Micro Silica and GGBS on Compressive Strength of Ternary Blended Concrete

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Abstract: **- Extensive research work for decades also in progress throughout the globe in concrete technology in finding alternative materials which can partially replace ordinary Portland cement (OPC) and which can also meet the requirements of strength and durability performance of industrial by products like Micro silica, ground granulated blast furnace slag, flyash, metakaolin, rice husk ash etc. now termed as complimentary cementitious materials (CCM) are quite promising. Subsequently these have led to the development of binary, ternary and quaternary blended concretes depending on the number of CCM and their combinations used as partial replacement materials. The Present experimental investigation is carried out in the optimization of a Ternary Blended Cementitious system based on Ordinary Portland Cement (OPC)/ GGBS / Micro Silica for the development of Ternary Blended Concrete. Compressive Strength of Ternary Blended Concrete at the ages of 7, 28, 60, 90 days for various combinations of Micro Silica and GGBS mixes were investigated. Micro Silica of 0%, 5%, and 10% and15% along with GGBS was replaced by 20%, 30% 40% and 50%. All the mixes were studied at water cement ratio of 0.55.**

Keywords: ***Ordinary Portland cement, Micro Silica, Ground Granulated Blast Furnace Slag (GGBS), Compressive Strength.***

I. INTRODUCTION

Now a day the world is witnessing the construction of very challenging and difficult structures, concrete being the most important and widely used structural material is called upon to possess very high strength. The main ingredient in the conventional concrete is Portland cement. The amount of cement production emits approximately equal amount of carbon dioxide into the atmosphere. Cement production is consuming significant amount of natural resources. To overcome the above ill effects, the advent of newer material and construction techniques and in this drive, admixture has taken newer things with various ingredients has become a necessity. The addition of pozzolanic materials with OPC a century old practice is an alternative in the construction industry. The ground granulated blast furnace slag is a waste product from the iron manufacturing industry, which may be used as partial replacement of cement in concrete due to its inherent cementing properties. 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 about 1500oC to 1600oC. The molten slag has a composition of 30% to 40% silicon dioxide (SiO2) and approximately 40% CaO, which is close to the chemical composition of Portland cement. Ground granulated blast furnace slag is off-white in Colour. This whiter colour is also seen in concrete made with GGBS, especially at replacements greater Than 50%.The main component of Blast furnace slag are CaO (30-35%), SiO2 (28-38%), Al2O3 (8-24%) and MgO (1-18%). Micro Silica in the ternary blend improves the early age performance of concrete and fly ash improves the properties at the later age. Silica fume was first discovered in Norway In 1947 when the environment controls started the filtering of the exhaust gases from furnaces. Silica fume can be utilized as material for supplementary cementations to increase the strength and durability. Micro Silica consists of fine particles with specific surface about six times of cement because its particles are very finer than cement particles.

II. LITERATURE REVIEW

Muhammad , Rizwan , Akram[1] Reported and describes the aim of research which was to evaluate the performance of OPC containing cement replacement materials in both binary and ternary system In this test variables different %of GGBS and MS are using as supplementary cementitious materials (SCM) . OPC was replaced with Micro Silica (SF) up to 7.5% and GGBS up to a level of 50%. The compressive strength of all the mixes was performed at 3, 7, 21, 28, and on 56 days duration. The use of SCM in the concrete mixes produced a lower strength value at the early age and gain in strength after 56 days is well pronounced for Mix A having 100% OPC is greater. *Surekha T; Dr. Chandrasekhar A[2]* was investigating the strength properties of GGBS & MS along with Polyvinyl Chloride (PVC) dust at the various replacement levels in M40 grade of concrete. A constant 8% of Micro Silica was used as on cement replacement for all the mix. Effect of GGBS was studied by replacing cement by 30 to 50% along with PVC dust 0 to 10% as additive. Mechanical Strengths such as compressive, Split Tensile & Flexural strength are investigated. This has made the researchers to use supplementary cementing material in making concrete. Compressive strength of MS with GGBS and without PVC dust was achieved more strength than the control Mix. The

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higher strength was gained up to 40% of cement replacement with GGBS than the normal concrete and then after strength decreases. There is a decrease in workability with constant 8% MS & increase Replacement level of GGBS (30% to 50%) and with 0% to 10% of PVC Dust. *Sowmya.S.M; Premanand Kumar; Amar.R*[3] In this Experimental study Mineral admixtures such as GGBS, MS and Fly ash are commonly used in concrete because they improve durability and reduce porosity as well as improve the interface with the aggregate the experimental work is carried out to investigate the optimum percentage of GGBS and MS to replace cement effectively. An attempt is made to replace cement with GGBS with an interval of 10% and SF by constant proportion for minimum grade concrete i.e., M20 and is tested for fresh and hardened properties to identify the optimum percentage of GGBS and silica fume in concrete. Workability has increased with the addition of GGBS. If further decreases with increase in percentage of GGBS. Split tensile strength will increased up to certain percentage with the addition of GGBS and it further decreases with increase of GGBS content in concrete *K.V.Pratap, M.Bhasker, and P.S.S.R.Teja*[4] Investigated the concept of triple blending of cement with GGBS and FLY-ASH, this triple blend cement exploits the beneficial characteristics of both Pozzolanic materials in producing a better concrete. 60 Cubes, 30 prisms and 30 cylinders are casted with M60 grade concrete. Twenty percent of cement is replaced by a combination of fly ash and Ground Granulated Blast Slag in different proportions. Compressive strength of cube specimen at 7 days and 28days, flexural strength of prisms at 7 days 28 days and split tensile strength of cylinder at 7 days and 28days are noted. The compressive strength, flexural strength and split tensile strength of concrete are improved with the addition of fly ash and GGBS as partial replacement to cement. The compressive strength of concrete is increased by a maximum of 11.13 % at 28days with (4+16) % replacement. The flexural strength of concrete is increased by a maximum of 11.74% at 28days with (4+16) % replacement. *D.Audinarayana, P.sarika, Dr.Seshadri Sekhar.T, Dr.Srinivasa Rao, and Dr P Sravana G.Apparao*[5] Investigated on the optimization of a Ternary Blended Cementitious system based on Ordinary Portland Cement (OPC)/ Fly Ash / Micro Silica for the development of high- performance concrete. Compressive Strength of Ternary Blended Concrete at the ages of 28, 90, 180 days for various combinations of Fly Ash and Micro Silica mixes were investigated. Fly Ash was replaced by 0%, 15% and 20% along with Micro Silica of 0%, 5%, and 10%. All the mixes were studied at three water cement ratios of 0.55, 0.45 and 0.35.When Fly Ash and Micro Silica are used in combination the beneficial effect of Fly Ash on fluidity can be used to compensate for the loss of workability with Micro Silica addition. The trend was reversed when the Micro Silica content increased from 5% to 10% for the same Fly Ash percentage (15%).For water to binder ratios the combination of 5% Micro Silica + 20% Fly Ash exhibited the least super plasticizer dosage while the mix 10% Micro Silica + 15% Fly Ash. The combination of 5% Micro Silica + 20% Fly Ash required the least dosage of superplasticiser for all the three W/B ratios studied. The combination of 5% Micro Silica + 15% Fly Ash performed the best at all ages and at all the Water cement ratios studied in terms of Compressive Strength among the four combinations. The combination of 10% Micro Silica + 20% Fly Ash gave the least Compressive Strength among the ternary mixes at all ages and at all Water cement ratio. *K. Suvarna Latha, M V Seshagiri Rao, Srinivasa Reddy. V*[6] made an effort to quantify the strength of ground granulated blast furnace slag (GGBS) and high volume fly ash (HVFA) at the various replacement levels and evaluates their efficiencies in concrete. The present study reports the results of an experimental study, conducted to evaluate the strengths and strength efficiency factors of hardened concrete, by partially replacing the cement by various percentages of ground granulated blast furnace slag and high volume fly ash for M20, M40 and M60 grades of concrete at different ages The partial replacement of cement with GGBS and HVFA in concrete mixes has shown enhanced performance in terms of strength and durability in all grades. This is due to the presence of reactive silica in GGBS and HVFA which offers good compatibility. *Deepa A Sinha*[7] Aimed to investigate the properties of ternary blended concrete incorporating Micro silica, metakaolin, and GGBS. The properties investigated include workability, compressive strength and. flexural strength. They replaced cement by ternary blend of Fly ash, metakaolin, Micro silica, GGBS up to 30% to determine the workability, compressive strength and flexural strength. The workability test results of ternary blended steel fiber reinforced concrete as measured from slump test, compaction factor test and Vee Bee test and flow test. The variation in slump, compaction factor, and Vee Bee time and % flow can be depicted in the form of graphs. Out of all pozzolonic material Micro Silica gives highest strength in flexure after 28 and 90 days. Micro Silica gives highest compressive strength after 90 days. Metakaolin gives highest compressive strength after 28 days. *A.K. Mullick*[8] Describes the characteristics of cementitious systems required to meet the diverse requirements of strength and durability of concrete and highlights the advantages of part replacement of OPC by fly ash, GGBS and MS– either singly or in combination in ternary blends. Examples of successful application are cited. With favorable raw materials in judicious raw mix design and due control in plant operations, it is possible to produce OPC having all the desirable characteristics to make concrete durable under different conditions of exposure during its service life. TBC of OPC with Micro silica and fly ash or GGBS are particularly useful to render greater durability to concrete. *C M Dordi, AN N Vyasa Rao and Manu*[9] Reported that the results indicate that MFGGBS addition in concrete improves cohesiveness, workability and workability retention in fresh state. The long term strength and permeability characteristics are also favorable. To have accrued benefits with MFGGBS, mix proportion is redesigned and trials are carried out to establish MFGGBS as a preferred additive for high performance fly ash based concretes. Use of fine and micro fine mineral additives in high performance concrete is a

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must to have improved characteristics both in fresh and hardened states.

III. RESEARCH SIGNIFICANCE

As Ternary Blends Possesses a number of advantages. It is essential that the fundamental behavior of ternary blended concrete is clearly understood. Hence the present research Programme aimed at generating experimental data necessary to study the behavior of Ternary Blended Concrete.

A. Objectives

The main objective of this experimental investigation is to study the effect of Ternary Blends on the Compressive Strength of Concrete. Experimental study is carried out by replacing cement with SCMs (Micro Silica (5%, 10% and 15%) and GGBS (20%, 30%, 40% and 50%)).considering water cement ratio 0.45 at the age of 7,28,60 and 90 days curing. Compressive Strength for all blended mixes at the age of 7, 28, 60 and 90 days was obtained.

IV. EXPERMENTAL PROGRAMME

The experimental programme was planned to produce a Ternary Blended Concrete with reduced cement content by adding different percentages of Micro Silica and GGBS. The material used and the experimental procedure for mixing, casting and testing of specimens are described in the following section. Total 156 specimens were casted to determine compressive strength of ordinary Portland cement and Ternary Blended Concrete at the age of 7, 28, 60 and 90 days.

A. Materials

Cement: Ordinary Portland cement of 53 grade having specific gravity of 3.15 was used. The Cement used has been tested for various proportions as per IS 4031-1988 and found to be confirming to various specifications of 12269-1987.

TABLE 1. Physical Properties of Cement

Properties	Cement
Specific Gravity	3.15
Consistency	30%
Setting Time of Cement	
Initial Setting Time	135min
Final Setting Time	240min
Soundness Test of Cement	1.5 mm

Micro Silica : Micro Silica -920D used was confirming to ATSM-C(1240-2000) and was supplied by " ELKEM South Asia (P) Ltd., Navi Mumbai in dry densified form was used. ". It is used as a partial replacement for cement.

GGBS: GGBFS which is available in local market, brought from JSW-HYD. The physical requirements in accordance with IS 1727- 1967 (Reaffirmed2008) and chemical requirements in accordance with IS: 12089 – 1987 (Reaffirmed 2008). The GGBFS is Fineness were found to be 2.2 and 3500 cm^2/gm

TABLE 2. Chemical Composition of Cement, GGBS and Micro Silica

Chemical Properties	**Cement**	**GGBS[10]**	**Micro Silica**
SiO_2 (%)	21.41	32.98	92.9
Al_2O_3 (%)	4.88	21.64	1.2
FeO_3 (%)	3.82	1.01	0.74
CaO (%)	63.69	35.95	0.02
MgO (%)	1.56	7.85	1
Loss on Ignition (%)	-	0.25	1.8
IR (%)	-	0.39	-
Mno (Manganese) Contant	-	0.12	-
Sulphide Sulphur (Na_2S) (%)	-	0.5	-
Glass Content (%)	-	90	-
Moisture Content (%)	-	4	0.7
Na_2O	0.47	0.31	0.42
K_2O		0.98	1.32
SO_3	2.36	0.85	0.1
Cl	-	0.008	-

Fine Aggregate: The locally available river sand is used as fine aggregate in the present investigation. The sand is free from clay, silt, and organic impurities. The sand is tested for various properties like specific gravity, water absorption and fineness modulus of fine aggregate were found to be less than 4.75 mm down confirms to IS : 383-1970,(Zone: II)

Coarse Aggregate: Machine crushed angular granite metal of 20mm nominal size from the local source is used as coarse aggregate. It is free from impurities such as dust, clay particles and organic matter etc., the coarse aggregate is also tested for its various properties.

TABLE 3. Physical Properties of Fine Aggregate and Coarse Aggregate

Properties	FA	CA
Partial Shape and Size	Round,4.75mm down	Angular ,20mm
Fineness Modulus	3.17	6.87
Silt Content	1.67%	-
Specific Gravity	2.6	2.9
Bulking of Sand	4.16%	
Bulk Density	1793kg/m3	1603kg/mm3
Surface Moisture	Nil	-
Water absorption	1.45%	0.39%

Water: Locally available Potable water confirming to IS 456-2000 is used.

Super Plasticizers: conplast SP430 is a chloride free, superplasticising admixture based on selected sulphonated naphthalene polymers. It is supplied as a brown solution which instantly disperses in water. Conplast SP430[11] disperses the fine particles in the concrete mix, enabling the water content of the concrete to perform more effectively. The very high levels of water reduction possible allow major increases in strength to be obtained

B. Mix Proportions

The objective was to produce Ternary Blended Concrete to meet required workability and to enhance compressive strength with Micro Silica and GGBS. Mix design is carried out as per

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guide line given in IS: 10262-2009, which yielded a proportion of 1:2.400:3.373 with water cement ratio of 0.55. To enhance workability a sulphonated naphthalene formaldehyde super plasticizer (SP430) was used at a dosage of 1litres/100kg by weight of cement. The quantity of material required per m3 of ordinary concrete is shown in

TABLE 4. Quantity of Material Required per 1m^3 of TBC (W/C=0.55)

Cement	Water	FA	CA
324	178	785	1093
1.000	0.550	2.400	3.373
11.352	6.243	27.471	38.255

TABLE 5. Mix Proportions of the Ternary Blended Concrete Mixtures per 1m^3

<table>
<tr><th>Mix ID</th><th>MIX Designation</th><th>Cement (kg)</th><th>MS (kg)</th><th>GGBS (kg)</th><th>FA (kg)</th><th>CA (kg)</th><th>Water (litres)</th></tr>
<tr><td>RM</td><td>OPC</td><td>324</td><td>0</td><td>0</td><td rowspan="13">785</td><td rowspan="13">1093</td><td rowspan="13">178</td></tr>
<tr><td>BM 1</td><td>MS 5%+GGBS 20%</td><td>243</td><td>16.2</td><td>64.8</td></tr>
<tr><td>BM 2</td><td>MS 5%+GGBS 30%</td><td>210.6</td><td>16.2</td><td>97.2</td></tr>
<tr><td>BM 3</td><td>MS 5%+GGBS 40%</td><td>178.2</td><td>16.2</td><td>129.6</td></tr>
<tr><td>BM 4</td><td>MS 5%+GGBS 50%</td><td>145.8</td><td>16.2</td><td>162</td></tr>
<tr><td>BM 5</td><td>MS10%+GGBS 20%</td><td>226.8</td><td>32.4</td><td>64.8</td></tr>
<tr><td>BM 6</td><td>MS10%+GGBS 30%</td><td>194.4</td><td>32.4</td><td>97.2</td></tr>
<tr><td>BM 7</td><td>MS10%+GGBS 40%</td><td>162</td><td>32.4</td><td>129.6</td></tr>
<tr><td>BM 8</td><td>MS10%+GGBS 50%</td><td>129.6</td><td>32.4</td><td>162</td></tr>
<tr><td>BM 9</td><td>MS15%+GGBS 20%</td><td>210.6</td><td>48.6</td><td>64.8</td></tr>
<tr><td>BM 10</td><td>MS15%+GGBS 30%</td><td>178.2</td><td>48.6</td><td>97.2</td></tr>
<tr><td>BM 11</td><td>MS15%+GGBS 40%</td><td>145.8</td><td>48.6</td><td>129.6</td></tr>
<tr><td>BM 12</td><td>MS15%+GGBS 50%</td><td>113.4</td><td>48.6</td><td>162</td></tr>
</table>

Triple Blended Concrete Mixes: Twelve Ternary Mixes (Cement+ Micro Silica+GGBS) were made with cement replacement. One Ordinary mix was established with only Portland cement. All the Ternary mixes were prepared with super plasticizer at a dosage of approximately 1.0 liters/100 kg of cement. Quantity of materials materials for Ternary mixes are shown in table 5.

C. Mixing, Casting, Curing, and Testing of Specimens.

Mixing: A total of 144 specimens were cast for each group of combination consists of Micro Silica and GGBS. Three groups of mixes were prepared each containing 48 cubes of 150mm size. Also 12 cubes were casted for ordinary mix with ordinary Portland cement only. All the concrete mixtures were mixed for a total of 4 minute in a laboratory by hand mixing. The constituent material at various mix proportions were thoroughly mixed in a dry condition to obtain uniform concrete mix. The quantity of water calculated as per water cement ratio was mixed thoroughly to obtain uniform cohesive concrete.

Casting of Specimens: For casting the cubes, standard cast iron metal moulds of size 150mm have been used. The moulds have been cleaned of dust particles and applied with mineral oil on all sides before concrete is poured into the mould. Thoroughly mixed concrete was placed layer by layer to cast the specimens. The specimens were prepared both by hand compaction as well as by imparting vibrating through vibrating table. The specimens were finished smooth and kept under wet gunny bags for 24 hours .Whole casting procedure is confined to Indian Standard: 10086-1882.

Curing the Specimens: After casting, the moulded specimens are stored in the laboratory free from vibration, in moist air and at room temperature for 24 hours. After this period, the specimens are removed from the moulds and immediately submerged in the clean fresh water of curing tank. The curing water is removed after every 5 days. The specimens are cured for 7, 28, 60 and 90 days.

Testing of Specimens: The specimens cured as explained above are tested as per Indian Standard: 516-1959 after removal from the curing tank and allowed to dry under shade.

Cube Compression Test: For the cube compression testing of concrete 150mm cube was employed. All the cubes were testing in saturated condition, after wiping out the surface moisture. For each trail mix combination, three cubes were tested at the age of 7, 28, 60 and 90 days of curing. The test was conducted as per I.S. (I.S.516-1959) standard test method. A cube was subjected to a concentrated compressive force where failure under compression was expected to occur. The test was carried out at uniform stress after the specimens has been centered in the testing machine.

Fig. 1 Mineral Admixtures

Fig. 4 Casting.

Fig. 2 Blending of SCMs

Fig. 5 Curing

Fig. 3 Vibrating Table

Fig. 6 Compression Test

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TABLE 6: Compressive Strength of TBC w.r.t Normal Concrete With 5% of Micro Silica and different % of MS and GGBS (W/C=0.55)

Mix ID	MS	GGBS	7 Days	28 Days	60 Days	90 Days
RM	0%	0%	18.31	30.52	32.65	35.58
BM1	5%	20%	19.27	32.50	34.93	38.77
BM2		30%	20.52	34.61	37.20	41.29
BM3		40%	20.28	34.33	36.90	40.95
BM4		50%	19.98	33.93	36.33	39.96

TABLE 7: Compressive Strength of TBC w.r.t Normal Concrete with 10% of Micro Silica and different % of G GBS (W/C= 0.55)

Mix ID	MS	GGBS	7 Days	28 Days	60 Days	90 Days
RM	0%	0%	18.31	30.52	32.65	35.58
BM5	10%	20%	19.83	33.57	35.95	39.54
BM6		30%	20.87	35.09	37.61	41.74
BM7		40%	20.48	34.48	37.23	41.32
BM8		50%	20.06	34.01	36.78	40.82

TABLE 8: Compressive Strength of TBC w.r.t Normal Concrete With 15% of Micro Silica and different % of GGBS (W/C= 0.55)

Mix ID	MS	GGBS	7 Days	28 Days	60 Days	90 Days
RM1	0%	0%	18.31	30.52	32.65	35.58
BM9	15%	20%	16.80	27.46	30.56	33.92
BM10		30%	17.86	29.20	31.49	34.91
BM11		40%	13.64	24.41	28.50	31.63
BM12		50%	12.25	22.89	26.44	29.08

TABLE 9: Maximum % Increase in Compressive Strength of TBC w.r.t Normal Concrete for Different Combination of MS and GGBS

MIX ID	7 Days	28 Days	60 Days	90 Days
MS 5% +GGBS 30%	12.07	13.40	13.94	16.05
MS 10% +GGBS 30%	13.98	14.97	15.19	17.31
MS 15% +GGBS 30%	-7.15	-4.33	-3.55	-1.88

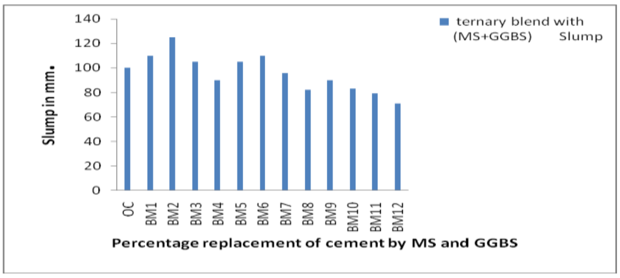

Fig. 1: Slump values with various proportions

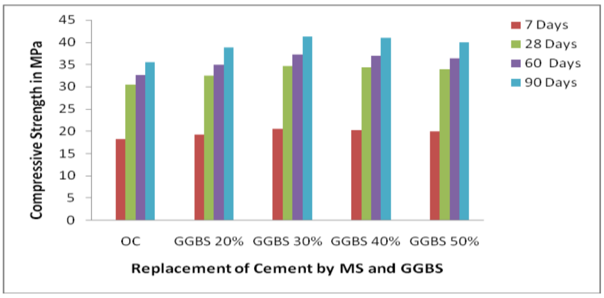

Fig. 2: Compressive Strength of TBC w.r.t Normal Concrete with 5% of Micro Silica and Different % of GGBS (W/C= 0.55)

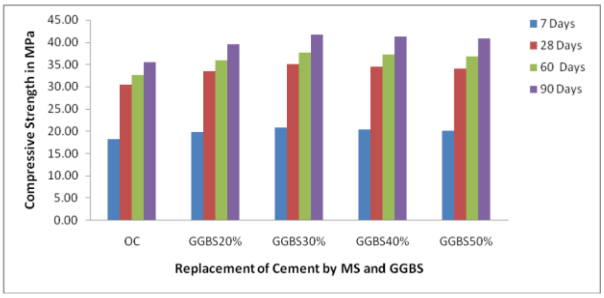

Fig. 3: Compressive Strength of TBC w.r.t Normal Concrete with 10% of Micro Silica and Different % of GGBS(W/C= 0.55)

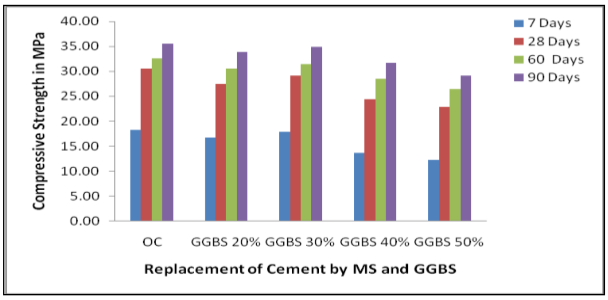

Fig. 4: Compressive Strength of TBC w.r.t Normal Concrete with 15% of Micro Silica and Different % of GGBS(W/C= 0.55)

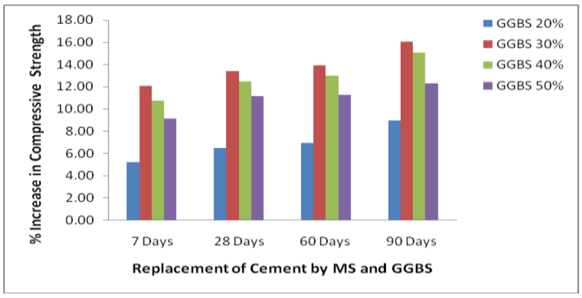

Fig. 5: % Increase in Compressive Strength of TBC W.r.t Normal Concrete (MS 5% and GGBS 20%, 30%, 40%, 50% (W/C= 0.55)

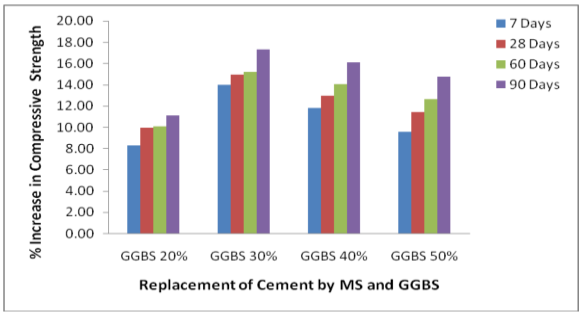

Fig. 6: % Increase in Compressive Strength of TBC w.r.t Normal Concrete (MS 10% And GGBS 20%, 30%, 40%50% (W/B= 0.55)

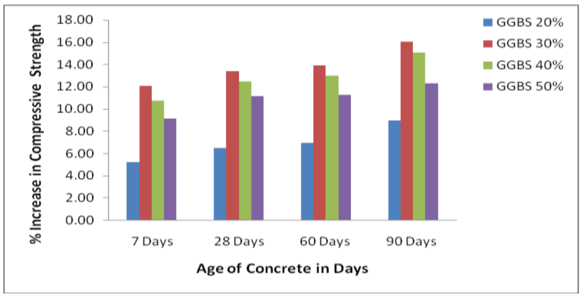

Fig. 7: % Increase in Compressive Strength of TBC w.r.t Normal Concrete (MS 5% and GGBS 20%, 30%, 40%50% Different Curing Days (W/B= 0.55)

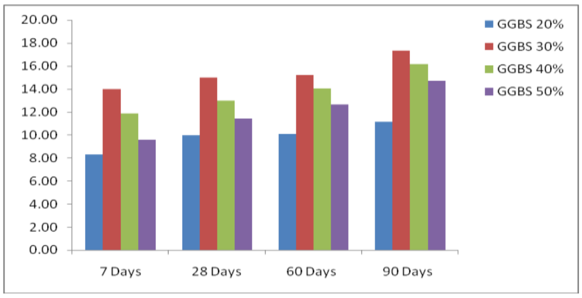

Fig. 8:% Increase in Compressive Strength of TBC w.r.t Normal Concrete (MS 10% and GGBS 20%, 30%, 40%50% Different Curing Days (W/B= 0.55)

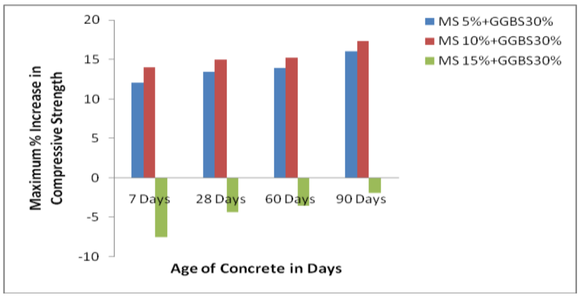

Fig. 9: Maximum % Increase in Compressive Strength of TBC w.r.t Normal Concrete for Different Combination of MS and GGBS (W/B=0.55)

V. OBSERVATIONS AND DISCCUSSION

A. Workability: Fig. 1 gives the workability test results of ordinary concrete and ternary mixes as measured from slump test. From the graph it is noted that workability of ternary blended concrete increases gradually until GGBS content reaches to 30% with Micro Silica(5%) as constant and it fall even in the increase of GGBS content. Increase of workability is in the range of 12.5% to 18.5%., when compare to ordinary concrete. Also the same trend was observed with Micro Silica (10%) as a constant at all percentages of GGBS. Increase of workability is in the range of 6.25% to 12.5%. But the percentage increase of workability is decreasing with increase of Micro Silica constant. This is due to the fact that the matrix content more fines. But the workability decreased with increasing quantity of Micro Silica (15%) for all percentage level of GGBS, when compared to ordinary concrete. This is due to the increase of the quantum of fine materials in the ternary mix. From the observation it is concluded that the optimum ternary mix (MS10%+GGBS 30%) exhibited more workable than ordinary concrete.

B.Compressive Strength: The variations in the strength of concrete with increasing replacement of ordinary Portland cement by SCMs (MS+GGBS) blends are summarized in the Tables 6 to 8. From the Table 6 it is observed that Micro Silica (5%) as constant, Compressive strength of ternary concrete increases gradually until GGBS constant reaches to 30%, and there after it falls even increase of GGBS content at all curing times. This is due to the combined effects of secondary pozzolonic reaction and the fineness of Micro Silica particles. It is observed that the same trend with MS (10%) as constant which is shown in Table 7. But it is noticed from Table 8 compressive strength of ternary concrete is decreased with MS (15%) irrespective of GGBS quantities when compare to ordinary concrete.

Increase in compressive strength: From the Table 6 and 7. It is observed that the compressive strength of ordinary concrete varies with respect to curing days and compressive strength of ternary mix varies with respect to percentage of Micro Silica and GGBS as well as curing days. From the Table 6 it is observed that strength of ordinary concrete varies from 32.51MPa to 60.42MPa for all curing days from 7 to 90. From the same Table, It is seen that the strength of ternary concrete varies from 34.50MPa to 70.25MPa for all curing days from 7 to 90. Table 7 shows that the strength of ternary concrete varies from 35.24MPa to72.16MPa. But it is noticed from the Table 8, the strength of ternary mix is less than that of ordinary concrete with replacement of cement by Micro Silica (15%)

Percentage increases in compressive strength of ternary mix are depicted in the form of figures 5 to 8,

Observations are made as follows:

- Replacement of Micro Silica (5%) and GGBS (30%), enhance the compressive strength of ternary mix 6.12% to9.25% more than ordinary concrete for 7 days to 90 days of curing.
- It is increased by 12.33% to 16.27% by replacing cement with Micro Silica (5%) and GGBS (30%).
- By replacing cement with Micro Silica (10%) and GGBS (20%) gives the compressive strength 8.4% to 12.38% and there is increase in compressive strength of ternary mix by 15.35% to 19.43% with replacement of Micro Silica (10%) and GGBS (30%).
- But the trend was reversed with the replacement of Micro Silica (15%) irrespective of GGBS

quantity.i.e.the strength of ternary concrete is decreasing gradually which is shown in the Table 8. Therefore, the optimum ternary mix is (MS 5%+GGBS 30%), beyond this combination decreasing trend in compressive strength is observed.

CONCLUSIONS

Following Conclusions are drawn from the observations and discussions of this investigation:

- The workability of fresh concrete increases with increase in GGBS content up to 30% replacement and density of fresh mix increases with Micro Silica and GGBS.
- Workability of concrete is getting reduced with increasing the mineral admixtures at higher percentages. These needs super plasticizers to maintain work abilities.
- The combinations of Micro Silica and GGBS is complementary, Micro Silica improves the early age performance of concrete with GGBS by refining the properties of hardened concrete continuously as it matures.
- As the curing period is extended the SCM mixtures with replacement of GGBS (50%), have higher strength than the base mix.
- Even in the early age (7 days) compressive strength development of the ternary concrete is slightly more than that of ordinary concrete. This trend is due to the presence of Micro Silica.
- The combination (MS 10%+GGBS 30%) gives more workable and highest compressive strength for all curing days when compared to ordinary concrete.
- Based on the above studies and test results, in case of ternary blended concrete. It is advisable to replace the cement by mineral admixtures at an optimum percentage of Micro Silica (10%) and GGBS (30%). At which we can get better results in workability and compressive strength comparatively with reference to ordinary concrete.
- Experimental studies a reveals that, the mineral admixtures plays on excellent performance in developing ternary mixes economically.
- By using industrial waste materials we can make environment more sustainable.

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