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AN INVESTIGATION ON COMBINED REPLACEMENT OF CEMENT BY GGBS AND NATURAL SAND BY SLAG SAND ON STRENGTH OF CONCRETE

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ABSTRACT

The utilization of waste materials from the industries has been continuously emphasized in the research work. The present work is to use GGBS (Ground Granulated Blast Furnace Slag) and Slag sand as combined replacement for ordinary Portland cement and river sand respectively. M20 grade of concrete with W/C 0.5 is carried out with two percentages of cement replacement by GGBS i.e, 35% and 45%, along with this the slag sand is varied from 0% to 100% in step of 20%. In first variation, 35%GGBS is replaced by cement and slag sand is varied as 0%, 20%, 40%, 60%, 80% and 100%. In second variation, 45% GGBS is replaced with cement and slag sand is varied as 0%, 20%, 40%, 60%, 80%, and 100%. For all mixes compressive strength, split tensile and flexural strength are determined at different days of curing. The strength of cube specimens varied from 21.55N/mm² to 33.61N/mm². The optimum strength of concrete Mix (30.19N/mm²) having 35%GGBS and 60% slag sand and strength of concrete Mix (33.16 N/mm²) having 45% GGBS and 40% slag sand replacements was considered to cast reinforced concrete beams. The beams are tested for flexure, under two point loading condition. Different parameters were investigated.

KEYWORDS: GGBS, Slag Sand, Compressive Strength, Split Tensile strength, Flexural Strength of prisms and Beams.

INTRODUCTION

Concrete is the largest man made material on earth. It contains cement, fine aggregate, coarse aggregate & water. Among these 70% to 75% volume of concrete is occupied by coarse and fine aggregate, rest of about 25% to 30% is cement and water in form of cement paste. Beside these elements, chemical and mineral admixtures are added to enhance the properties of concrete. The large production of cement causes destruction of environment (Global Warming) and the continues use of Natural Sand leads to the depletion of river beds results into the ecological imbalance. Therefore the replacement of cement and natural sand by the waste industries by-products (Mineral admixtures) has been continuously emphasized during recent years. In this study, the cement is replaced by GGBS (Ground Granulated Blast furnace slag) and natural sand is replaced by slag sand in various percentages. GGBS and slag sand are waste product obtained from Iron and steel manufacturing industry. Therefore the disposal problem of waste material is solved side by side the saving of cement and natural sand can be done. Hemanth v [1], he presents the investigation on the combined replacement of cement by fly ash and natural sand by slag sand on strength of concrete. Fly ash was kept as 30% replaced with cement and slag sand was varied as 10% to 50% with 10% variation. The fresh and hardened concrete properties shows good results as compared with conventional concrete. The optimum percentage replacement results were incorporated into singly reinforced concrete beams for evaluation of flexural behavior of beams. The beams also shows sufficient results. P.S.Kothai [3], investigate the utilization of steel slag as replacement for fine aggregate. The steel slag sand is varied from 0% to 50% with 10% variation. The results shows up to 30% replacement the strength increases. They have concluded that the optimum steel slag replacement is 30%. Sagar Patel [5], evaluates the flexural behavior of RCC beams by replacing cement by GGBS and fine aggregate by slag sand. M40 grade of concrete with W/C =0.4 were used. The slag sand of 40% is kept constant whereas the cement was replaced as 0%, 30%, 40%,and 50%. The optimum replacement was found to be 40% slag sand and 40% GGBS. The beams are casted and tested for studying flexural behavior of beams. The replacement beams shows large load carrying capacity compared to conventional concrete.

EXPERIMENTAL PROGRAMME

Materials Used

In present work various materials is used with their respective properties namely: OPC 53 Grade cement. GGBS, Fine aggregates: Natural sand and Slag Sand (SS), Coarse aggregate, water.

a. Cement: Ordinary Portland cement of 53 grade confining to IS: 12269-1987 has been used. The physical properties of the cement obtained on conducting appropriate tests as per IS: 12269-1987.

b. GGBS: GGBS used in this work is from JSW Cement company. The physical properties were: Specific gravity= 2.72, colour = Off-white as per IS: 4031-1988.

c. Natural Sand: Locally available clean river sand passing through sieve size 4.75mm down and retained on 150µ have been used. The sieve analysis test is done as per IS: 383-1970. The natural sand was of Zone II , Fineness Modulus= 2.84, specific gravity= 2.63.

d. Slag Sand: The slag sand used in this work was collected from JSW steel plant, Bellary. The tests were carried as per IS: 383-1970. Slag sand was of Zone II, Fineness modulas = 2.97 and specific gravity= 2.61.

e. Coarse aggregate: The coarse aggregate used is crushed (angular) aggregate confirming to IS: 383-1970. The maximum size of aggregate used is 20 mm down. The result of sieve analysis conducted as per the specification of IS 383-1970. Fineness Modulus= 5.124, Specific gravity= 2.72.

f. Water : Clean potable water is used for casting and curing operation for this work. The water used in this project work is of potable standard with pH= 7.5.

Mix proportion

Concrete Mix design of M20 grade was designed conforming to IS: 10262-2009. The trial mixes were attempted to achieve workable concrete mix. Cubes of standard size 150x150x150mm, cylinders of size 150mm diameter and 300mm height, prisms of size 500x100x100mm were casted.

Table1 : Design parameters per cubic meter

Cement	383.16kg
Fine aggregate	671.961kg
Coarse aggregate	1141.693kg
W/C ratio	0.5
Water	191.58 litres

In this investigation, In first variation, 35% GGBS is replaced by cement along with Slag Sand is replaced by Natural sand as 0%, 20%, 40%, 60%, 80% and 100%. In second variation, 45% GGBS is replaced by cement and Slag sand is varied similarly- 0%, 20%, 40%, 60%, 80% and 100%. The Mix proportion were 1: 1.75:2.98.

Properties Of Fresh Concrete

Concrete mixes were checked for workability through slump and compaction factor tests. It was observed that the slump flow increases as the GGBS content increases whereas slump decreases for higher percentage of slag sand replacement. All concrete mixes was homogenous and cohesive in nature also slump had shear type of failure. The value of slump ranges from 100mm to 65mm. Based on this, 75mm slump is taken in Mix design of Concrete.

Fig 1: Slump Test On Fresh Concrete

Hardened Concrete properties

Compressive strength, Split tensile strength and Flexural strength (Modulus of rupture) of different mixes were determined.

Compressive strength

The Cubes of 150x150x150mm sizes are casted for various combined mixes. The Cubes are cured and tested for 7 and 28 days. Testing was made in 2000 KN testing machine with loading rate of 140 kg/cm/m². The average of 3 cubes for each curing and each replacement is note down to get the compressive strength of concrete. Fig 2 shows the results of the first variation containing 35% GGBS and various slag sand replacement. Fig 3 shows the results obtained for 45% GGBS and various slag sand percentages replacement.

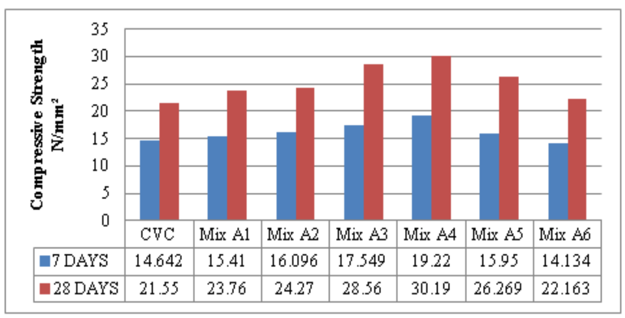

Fig 2: Compressive strength of M20 grade of CVC and Mixes A1 to A6

Here, Mix A1 represents 35% GGBS replaced by cement and 0% slag sand(SS) replaced by natural sand. Similarly Mix A2-GGBS35%SS20%, Mix A3-GGBS35%SS40%, Mix A4-GGBS35%SS60%,
Mix A5-GGBS35%SS80% and Mix A6-GGBS35%SS100%. CVC represents Conventional concrete.

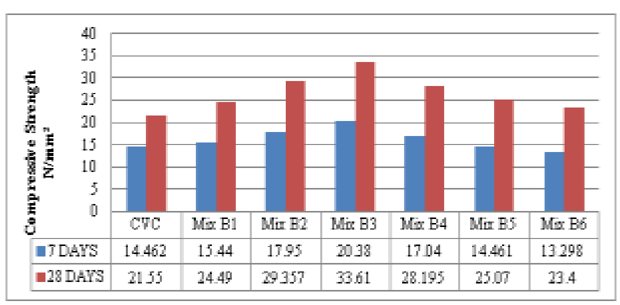

Fig 3: Compressive strength of M20 Grade of CVC and Mixes B1 to B6

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Here, Mix B1 represents 45% GGBS replaced by cement and 0% slag sand(SS) replaced by natural sand. Similarly, Mix B2-GGBS45%SS20% , Mix B3-GGBS45%SS40%, Mix B4-GGBS45%SS60% ,Mix A5-GGBS45%SS80% and Mix A6-GGBS45%SS100%.. CVC represents Conventional concrete.

The test results shows that the compressive strength is increased as the percentage of slag sand increased. The strength increases upto 60% slag sand for 35% GGBS and upto 40% slag sand for 45% GGBS. For 100% replacement, the strength is nearly similar to that of conventional concrete. But for durability and other environmental effects, the maximum strength can be considered as optimum replacement. Hence Mix A4 (35% GGBS+60%SS) and Mix B3 (45%GGBS+40%SS) can be considered as optimum combined replacement and can be used in place of conventional concrete.

Split Tensile strength

The split tensile strength is the indirect test to determine the strength of concrete. Three cylinders of size 150mm diameter and 300mm in length are casted for various percentages of GGBS and slag sand and cured for 28 days. Testing was made in 2000KN testing machine as per IS:516-1959. The magnitude of split tensile strength is given by fct = 2P/πdl, where P= applied compressive load at failure, d= Diameter of cylinder, l= Length of cylinder. Average of 3 cylinders gives the split tensile strength.

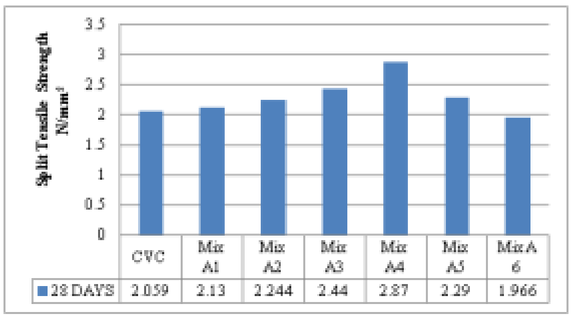

Fig 4: Split tensile strength of M20 Grade of CVC and Mixes A1 to A6.

The results above shows that there is an increase in strength upto 60% slag sand and 35%GGBS replacement (Mix A4). The 100% replacement shows less strength, this may be because of high glass content.

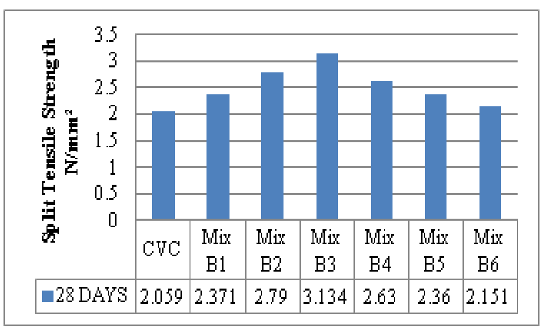

Fig 5: Split tensile strength of M20 grade of CVC and Mixes B1 to B6

The results obtained shows that the strength is increase upto 45%GGBS replaced by cement and 40% slag sand replaced by natural sand. Further for 100% slag sand replacement the strength is comparable to conventional concrete.

Flexural Strength

Three prisms of size 500x100x100mm were casted and cured for 28 days for every combined replacement of GGBS and Slag Sand(SS). Testing was done as per two point loading method. The results of various mixes is shown in Fig 6 and Fig 7.

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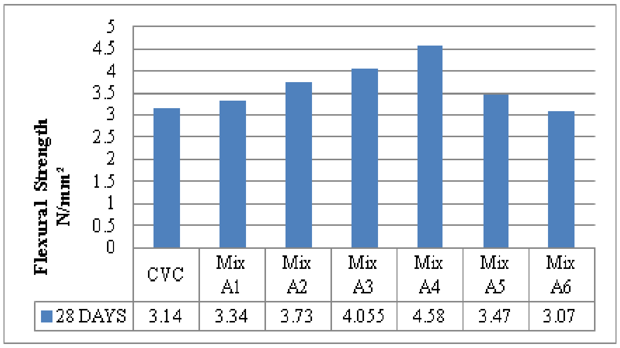

Fig 6: Flexural strength of M20 Grade of CVC and Mixes A1 to A6

The flexural strength increases slightly from 0% to 60% slag sand and then the strength decreases for 80% and 100% slag sand content. The optimum percentage can be taken as 35% GGBS and 60% slag sand (Mix A4).

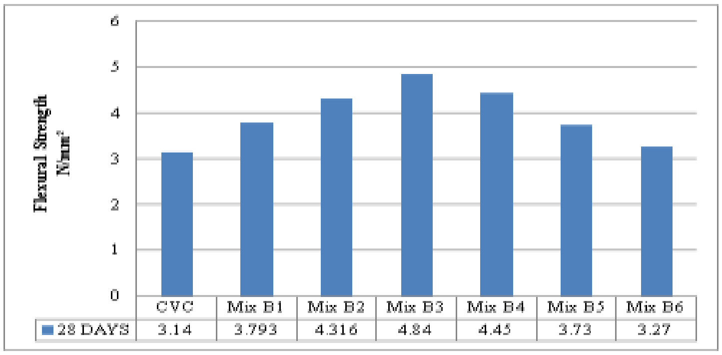

Fig 7: Flexural strength of M20 Grade of CVC and Mixes B1 to B6

The flexural strength increases slightly from 0% to 40% slag sand and then the strength decreases. The optimum percentage can be taken as 45% GGBS and 40% slag sand (Mix B3).

Flexural Behavior of Beams

Geometry of test beams

The dimension of beams were selected as 700x150x150mm. The testing is done under Universal testing machine under two point loading condition. The dimension is given below:
Overall length, L= 700mm
Effective length, L_{eff} = 600mm
Overall Depth, D = 150mm
Overall Breadth, B = 150mm
Effective depth, d = 120mm

Table 2: Details of Test Beams

Beams	Mix designation	Beam dimension (mm)	Reinforcement		Tensile reinforcement ratio (%)
			Compression	Tension	
B1,B2,B3	CVC	150x150x700mm	2#8	2#10	0.87%
B4,B5,B6	Mix A4	150x150x700mm	2#8	2#10	0.87%
B7,B8,B9	Mix B3	150x150x700mm	2#8	2#10	0.87%

Test setup and testing procedure

The testing is done in Universal testing machine. All beams were tested under two point loading method. One dial gauge was placed at the centre of beam to note the deflection at mid span. The loading was done at the rate of

400kg/min which is placed centrally over the channel section ISMC 250.The Crack load, service load and ultimate load and their corresponding deflections were recorded. The Loading is continued until the failure of beams. The Loading arrangement is shown in Fig 8.

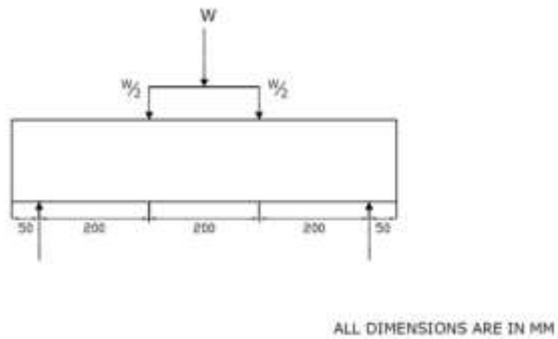

Fig 8: Loading Arrangement For Testing Of All Beams

RESULTS AND DISCUSSIONS

Crack pattern

All 9 beams were failed in flexural. As the load increases, the crack started from bending zone at the mid span of beam. The cracks at the mid span opened widely near failure. At failure, Flexural cracks were observed.

Fig 9: Crack Pattern Of Test Beam

Experimental Results

All the beams were studied for bending under flexural mode. Structural parameters such as cracking load, service loads, ultimate loads and their corresponding deflections were investigated. Also, experimental moments of cracking and ultimate loads is calculated and compared with the theoretical moments (IS: 456-2000). The results are tabulated in tables 3 to 5.

Table 3: Average Experimental results of test beams

Beam No.	**Ast**	**Experimental Values**								
		Pcr	Avg Pcr	Δcr	Ps	Avg Ps	Δs	Pu	Avg Pu	Δu
B1	0.87%	25		0.95	78		1.8	141		2.9
B2	0.87%	22	23.5	0.95	71	73	1.8	137	139	2.7
B3	0.87%	23.5		0.9	70		1.8	139		2.7
B4	0.87%	23	27	1.1	80	85	1.8	156	157	3.1
B5	0.87%	30		1.1	90		1.8	158		3.4

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B6	0.87%	28.0		1.2	85		1.7	157		3.3
B7	0.87%	32	33.00	1.1	110	101.67	2.0	166	166.33	3.6
B8	0.87%	35		1.2	105		2.0	169		3.7
B9	0.87%	32		1.2	90		1.9	167		3.4

Here Pcr = Cracking load, Ps = Service load and Pu = Ultimate load and their corresponding deflections Δcr, Δs and Δu respectively.

Deflection
The deflection was measured at the mid span of beam and the corresponding loads were noticed. The results show the load deflection behavior of beams.

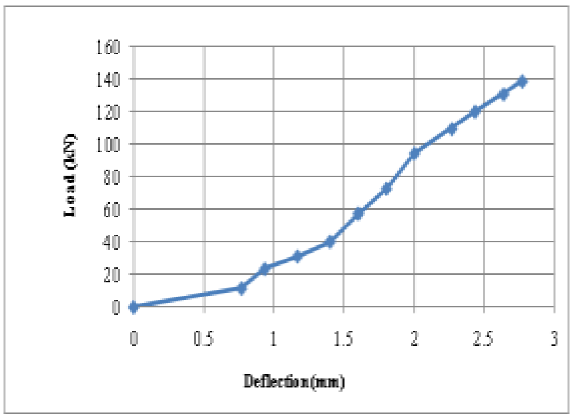

Fig 10: Average Load vs Deflections of Beams- B1,B2,B3

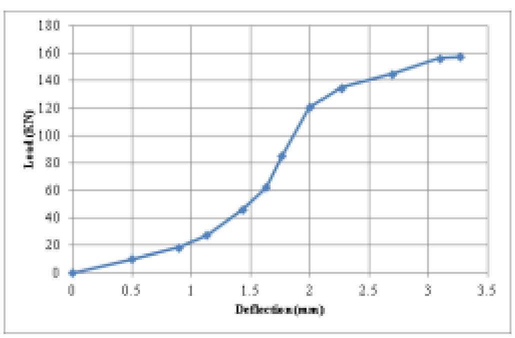

Fig 11: Average Load Vs Deflections of Beams- B4,B5,B6

Fig 12: Average load Vs deflections of beams- B7,B8,B9

Cracking Moment
The load at which first crack was observed is noticed and was calculated as cracking moment. The Theoretical cracking moment is calculated as per IS:456-2000. The Experimental values was compared with theoretical moment and it was found that the experimental values is more than the theoretical values. The table 4 shows the results :

Table 4: Experimental Results And Theoretical Results Of Cracking Moments

Beam Designation	**Ast**	**Max Compressive strength**	**Modulas of rupture Fcr=0.7√fck**	**Experimental Cracking Moment Mc (KNm)**	**Theorotical Cracking Moment Mr (KNm) IS:456-2000**	**Ratio Mc/Mr**
B1,B2,B3	0.87%	33.61	4.058	2.35	2.283	1.03
B4,B5,B6	0.87%	33.61	4.058	2.7	2.283	1.183
B7,B8,B9	0.87%	33.61	4.058	3.3	2.283	1.445

Flexural Capacity

The theoretical ultimate moment is calculated as per Is:456-2000. The experimental ultimate moment is compared with the theoretical moment. The results are shown below table 5 :

Table 5: Experimental Results AND Theoretical Results OF Ultimate Moments

Beam Designation	**Ast**	**MAX Compressive Strength**	**Average Mid Span Deflection (Mm)**	**Experimental Ultimate Moment Mu,e (kNm)**	**Theorotical Ultimate Moment Mu,t (kNm) IS:456-2000**
B1,B2,B3	0.87%	33.61	2.767	13.9	5.573
B4,B5,B6	0.87%	33.61	3.267	15.7	5.573
B7,B8,B9	0.87%	33.61	3.567	16.633	5.573

From the above table we can see that there is increase in the Experimental ultimate moment carrying capacity compared to theoretical ultimate moment carrying capacity of Beams.

CONCLUSIONS

1. The Workability property of concrete property decreases as the percentage of replacement of slag sand increases. The slump varies from 65mm to 100mm for different mixes. By addition of GGBS, the slump is slightly improved and all the concrete mixes were homogenous and cohesive in nature.
2. The compressive strength of cubes are increased with addition of GGBS and Slag Sand. The Optimum percentages of replacements obtained are – 35%GGBS replaced by cement and 60% slag sand replaced with Natural sand. Similarly for 45% GGBS and 40% slag sand replacement the compressive strength is higher than all other mixes.
3. Split tensile strength of Mix A4 (35%GGBS+60%SS) and Mix B3(45%GGBS+40%SS) has highest strength as compared to conventional concrete.
4. The Flexural strength of concrete is also maximum for 35% replaced by cement and 60% slag sand replaced by natural sand. However 45%GGBS and 40% slag sand shows highest flexural strength values.
5. For cubes, cylinder and prism, the conclusion is that the optimum replacement can be done in two combinations: 35% GGBS can be replaced by cement along with 60% slag sand by natural sand. B- 45% GGBS can be replaced by cement along with 40% slag sand by natural sand.
6. Due to high glass content, the higher replacements show decrease in strength of concrete(Mix A5,A4,B4,B5,B6). Therefore Mix A4 and Mix B3 is incorporated in beams to study flexural behavior of singly reinforced RC beams.
7. All beams were designed as per IS:456-2000 and under reinforced section is designed . The beams fails under flexure. The flexural crack propagated from tension fiber to compression. No horizontal cracks were observed at the level of replacement, indicating no bounding failure.
8. The deflection and load carrying capacity of beams containing GGBS and slag sand is more as compared to conventional concrete.
9. An increase in cracking moment of about 12.96% for Mix A4 and 28.79% for Mix B3, for same tensile reinforcement is observed compared to conventional concrete. The experimental ultimate moment carrying capacity of test beams are also greater than the theoretical moment carrying capacity.
10. Hence, it can be recommended that the GGBS and Slag Sand can satisfactorily utilize as Combined partial replacement for Cement and Natural sand respectively in concrete.

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