Studying the Properties of Concrete with Copper Slag and Glass Wool Fibre

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Abstract – The present scenario of modern concrete technology is towards increasing the strength and durability of concrete to meet the demands of the modern construction world at lower cost and towards increasing the use of waste materials as replacement in concrete ie.to follow resource efficiency. These factors can be achieved in concrete by adding natural or synthetic fibre and other materials such as slag being produced by Sterlite Industries. The basic purpose of using Glass Wool Fibre is to reduce the cost of concrete because Glass Fibre is very costly and use of Copper Slag will balance the ecosystem as it's a waste material. Hence, research has to be done to provide an alternative use of Glass Fibre. In the present study, Glass wool fibre and Copper Slag is added and replaced by fine aggregate respectively to the concrete to increase the strength as compared to the control concrete. The strength parameters of concrete such as Workability, Compressive Strength and Split Tensile Strength were studied by varying the percentage of Glass Wool fibre from 0.2% to 0.8% to the total weight of concrete at 40% replacement of fine aggregate by copper slag and before doing this test were conducted on variation of Copper Slag percentage from 10% to 60% and Glass Wool Fibre in variation (0.2%,0.4%,0.6%0.8%) individually on M-25 Grade of Concrete. Cubes of Sizes (150mm*150mm*150mm) and Cylinder of size (150 mm Dia. And Length 300mm) were casted and cured for 7&28 days and then the specimen were tested.

Index Terms – Concrete, Copper Slag, Glass Wool Fibre, Workability, Compressive Strength, Split Tensile Strength.

1. INTRODUCTION

One of the most important material used in construction industry is concrete. It perfectly matches with several requirements like strength, durability, impermeability, and fire-resistance and abrasion resistance. India uses about 7.3 million cubic meters of ready-mixed concrete each year. It is used in highways, bridges, high-rise buildings, dams, homes, and so many other numerous applications. The sustainable development for construction involves the use of nonconventional and innovative materials, and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways conserving the environment. Copper slag is one of the materials that are considered as a waste material which could have a promising future in construction industry as partial or full substitute of either cement or aggregates (Gorai *et al*, 2003)[1].

It has been experimentally studied that concrete reinforced with right amount of fibre will give better performance in Compression, Flexure and Tensile Strength but the amount of improvement depends on type of fibre used.

Glass Wool Fibre is one of other material that can be used enhance the properties of concrete as the use of Glass Fibre increases the cost of concrete. As we know that concrete possesses high compressive strength and low tensile strength which can be improved by reinforcing concrete with fibres. Olutoge et al (2015)[2] have studied concrete by reinforcing it with Glass Wool Fibre and found increase in split tensile strength.

2. EXPERIMENTAL INVESTIGATION

The experimental Programme involves various processes of material testing, mix proportioning, mixing, casting and curing of test specimens which is elaborated in the following sections. All the experiments were done in the material testing laboratory, Integral University Lucknow.

2.1. Materials Used

a) Ordinary Portland Cement (43 Grade)
b) Fine Aggregate
c) Coarse Aggregate
d) Water

e) Copper Slag
f) Glass Wool fibre
g) Superplasticizer

a) Cement

Ordinary Portland cement of 43 grade were used, conforming to recommendations stated in IS 4031(1999). The normal consistency was 30%. Initial and final setting time of the cement was 30 min and 610 min, respectively.

b) Fine Aggregate

Fine aggregate can be natural or crushed. Locally available river sand passing through 4.75 mm IS sieve and it conforms to zone II (Asper IS 383 – 1970). The specific gravity and fineness was found to be 2.6 and 3.13.

Physical properties and sieve analysis is given in table 1& 2.

Table-1

Physical Properties of Fine Aggregate		
Properties	Observed Values	Recommended Values
Grading Zone	Zone II	-
Specific Gravity	2.606	2.6-2.7
Fineness Modulus	3.13	2.9-3.2

Table-2

Sieve Analysis of Fine Aggragate						
					Amont Taken=1000 gm	
IS Sieves	Weight retained(g)	Cumulative weight retained(g)	Cumulative % Weight Retained	Wt. Passing (gm)	% Passing	Remark
10mm	0	0	0	1000	100	Zone II
4.75m	95	9.5	9.5	905	90.5	
2.36m	93	9.3	18.8	812	81.2	
1.18m	182	18.2	37	630	63	
600µ	177	17.7	54.7	453	45.3	
300µ	397	39.7	94.4	56	5.6	
150µ	45	4.5	98.9	11	1.1	

c) Coarse Aggregate

Two single sized crushed stone aggregates ranging from 12.5 mm to 2.36 mm and 20 mm to 4.75 mm (10mm and 20mm sizes) were used in respective proportions in concrete mixes. The test procedures as mentioned in IS-383(1970) were followed to determine the physical properties of sand. The results obtained are tabulated in Table-2.

d) Water

The Water used for mixing concrete should be portable drinking water having pH value of 7 and the water is free from organic matter and the solid contents should be within the permissible limits as per IS 456-2000 & and conforming to IS 3025.1964.

Table-3

Physical Properties of Coarse Aggregate			
Physical Properties	Observed values		Recommended values
	10mm aggregate	20mm aggregate	
Fineness Modulus	6.28	7.11	6.5-8.0
Aggregate crushing value(%)	18.15	25.13	Not more than 45%
Aggregate impact value(%)	28.63	22.1	Not more than 45%
Specific Gravity	2.6		-

e) Copper Slag

Copper slag is an industrial by-product material produced from the process of manufacturing copper. Generally for the production of 1 Tonne of Copper 2.3-3.0 tonne of Copper Slag is generated as waste (Shi et al (2008))[3], about 2600 tons of CS is produced per day and a total accumulation of around 1.5 million tons. This slag is currently being used for many purposes ranging from land-filling to grit blasting. These applications utilize only about 15% to 20% and the remaining dumped as a waste material and this causes environmental pollution. Some researchers also considered copper slag as a good candidate for the replacement of aggregates in concrete and probably also as cement replacement due to its physical and chemical properties (Mavroulidou M.et al, 2015)[4]. In addition copper slag has been excluded from the listed hazardous waste category of the United States Environmental Protection.

Copper Slag is a glassy granular material with high specific gravity. Particle sizes are of the order of sand and have a potential for use as fine aggregate in concrete. Sieve analysis of copper slag is tabulated in Table-4.

Table-4

Copper Slag Sieve Analysis			
Sieve Size (mm)	Wt. Retained (gm)	Total Net Wt.	% Retained on each Sieve
2.36	130	1000	13
2	144	1000	14.4
1.7	280	1000	28
1.18	226	1000	22.6
0.85	168	1000	16.8
0.71	49	1000	4.9
0.6	2	1000	0.2
0.25	1	1000	0.1

f) Glass Wool Fibre

Glass wool, which is one product called "fibreglass" today, was invented in 1938 by Russell Games Slayter of Owens-Corning. It is an insulating material made from fibres of Glass arranged using a binder into a texture similar to wool.

Glass Wool is manufactured by the fusion of a mixture of natural sand and recycled glass at 1450 °C, the glass that is produced is converted into fibres. It is typically produced in a method similar to making cotton candy, forced through a fine mesh by centripetal force, cooling on contact with the air. It was established by Gowri .et al (2013)[5] that the presence of glass wool fibre in concrete increases the concrete strength properties and also serves as cracks arrestor. In the present study the amount of fibre to be added in a concrete mix is measured as a percentage of the total weight of the concrete. The fibres with the Modulus of Elasticity of 55 GPa, Specific gravity 2.68 and Aspect Ratio of 1750 is used given in table-5.

Table -5

Properties of Glass Wool Fibre	
Fibre	Glass Wool
Specific gravity	2.6
Modulus of elasticity (GPa)	55
Length (mm)	14
Diameter (micron)	8
Aspect ratio	1750
Effect of temperature	Non-combustible

g) Superplasticizer

High range super plasticising admixture complies with IS-9103-1999 and BS 5075 part-3. It is a PC-Based superplasticizer it speeds up construction, increases workability.

2.2. Concrete Mix Proportions

The mixture proportioning was done according the Indian Standard Recommended Method IS 10262- 2009 and with reference to IS 456-2000. M-25 grade of concrete was designed. The target mean strength was 31.1 MPa for the OPC control mixture, the total cement content was 443 Kg/m3, fine aggregate was taken 745.3 Kg/ m3 and coarse aggregate was taken 1026.9 Kg/m3. The water to binder ratio was kept constant as 0.40. The total mixing time was 5 minutes; the samples were then casted and left for 24 hrs before demoulding. They were then placed in the curing tank until the day of testing cement, A homogenous mix was prepared by adding and mixing coarse aggregate, fine aggregate, cement plasticizer was added by weight in ratio (1:1.68:2.31) before water was added and properly mixed together to achieve homogenous material.

Table-6

Mix Proportion for M-25	
Ingredients	**Qty. in Kg**
CEMENT	443.61 Kg
WATER	177.44 Litre
PLASTICIZER	1.529 Litre
COARSE AGGREGATE	1026.9 kg
FINE AGGREGATE	745.3 Kg

2.3. Methodology

In the present study we have done individual experiments on properties of concrete by varying the percentage of Copper Slag and Glass Wool Fibre and after getting the result we have replaced fine aggregate by copper slag and varied the percentage of Glass Wool Fibre.

We have performed workability test, Compressive Strength Test, Split Tensile Strength Test on individual and on varying percentage of Glass Wool Fibre by replacing Fine Aggregate by 40% Copper Slag . A total 135 specimen were casted comprising of cube (150mmx150mmx150mm) and cylinder of 150 mm diameter and 300mm length. Following specimen were casted and tested in three phases one with copper slag other with glass wool fibre and the last with combination of both on M-25 grade of concrete. In table-7 we have provided mix-id of sample that has to be casted on all three variations.

Table-7

Mix-ID of different Variation					
Copper Slag		**Glass Wool Fibre**		**Addition of G.W.F. at 40% replacement of F.A. by C.S.**	
Variation %	**Mix-ID**	**Variation %**	**Mix-ID**	**Variation %**	**Mix-ID**
0%	N	0%	N	0.2% G.W.F.	Mix-1
10%	C-10%	0.20%	G-0.2%	0.4% G.W.F.	Mix-2
20%	C-20%	0.40%	G-0.4%	0.6% G.W.F.	Mix-3
30%	C-30%	0.60%	G-0.6%	0.8% G.W.F.	Mix-4
40%	C-40%	0.80%	G-0.8%		
50%	C-50%				
60%	C-60%				

3. TESTS AND RESULTS

Compressive strength test were conducted to evaluate the strength development of concrete mix containing CS, GWF, and combination both of GWF & CS as given in Table-7 at the age of 7, 28, days respectively. The cylindrical specimens were also cast for finding the split tensile strength at 28 days for each mix specification following the standard test procedure.

3.1 . Copper Slag Test Result

Effect of Copper Slag on strength of concrete on varied percentage as replacement of fine aggregate is given in table-8 & 9.

Table-8

Compressive Strength & Workability Test on Copper Slag								
Cube ID	Weight (kg)	Slump	7 Days			28 Days		
			Avg. Load (KN)	Strength (Mpa)	% increase in strength	Avg. Load (KN)	Strength (Mpa)	% increase in strength
N	8.37	100	506.36	22.51		723.4	32.15	
C-10%	8.45	92	508.91	22.62	0.50%	737.6	32.78	1.95%
C-20%	8.53	85	507.78	22.57	0.20%	725.4	32.24	0.28%
C-30%	8.37	82	557.53	24.78	10.10%	780.8	34.7	7.93%
C-40%	8.66	80	544.32	24.19	7.40%	802.8	35.68	10.98%
C-50%	8.8	83	514.08	22.85	1.52%	734.4	32.64	1.52%
C-60%	8.85	88	448.23	19.92	-11.48%	672.3	29.88	-7.06%

Table-9

Split Tensile Strength Test on C.S.					
Cube ID	Weight (Kg)	Slump	Average Load (KN)	Split Tensile Strength	% increase in strength
N	13.1	100	283.3	4.01	
C-10%	13.3	92	289	4.09	1.99%
C-20%	13.4	85	284.7	4.03	0.50%
C-30%	13.1	82	296.7	4.2	4.73%
C-40%	13.6	80	308	4.36	8.73%
C-50%	13.8	83	288.3	4.08	1.74%
C-60%	13.9	88	251.5	3.56	-11.22%

3.2. Glass Wool Fibre Test Result

Effect of G.W.F. on strength of concrete on varied percentage as an additive in concrete given in table-10 & 11.

Table-10

Compressive Strength Test Result on G.W.F.								
Cube ID	Weight	Slump	7 Days			28 Days		
			Average Load (KN)	Strength (Mpa)	% increase in strength	Average Load (KN)	Strength (Mpa)	% increase in strength
N	8.37	100	506.3	22.51		723.38	32.2	0
G-0.2%	8.18	92	551.93	24.53	8.99%	766.8	34.1	6.00%
G-0.4%	8.3	83	541.35	24.06	6.90%	762.75	33.9	5.44%
G-0.6%	8.25	75	500.4	22.24	-1.17%	667.35	29.7	-7.74%
G-0.8%	8.05	60	460.13	20.45	-9.13%	666.9	29.6	-7.80%

Table-11

Split Tensile Strength Test on G.W.F.					
Cube ID	Weight (Kg)	Slump	Average Load (KN)	Split Tensile Strength (Mpa) at 28 days	% increase in strength
N	13.13	100	283.3	4.01	
G-0.2%	12.842	92	311.6	4.41	9.97%
G-0.4%	13.027	83	298.9	4.23	5.48%
G-0.6%	12.944	75	261.9	3.7075	-7.54%
G-0.8%	12.64	60	261.8	3.705	-7.60%

3.3. Glass Wool Fibre and Copper Slag Test Result

Effect of G.W.F. on the properties of concrete in which are fine aggregate is replaced by 40% copper slag. Different mixes were prepared varying the percentage of G.W.F. as given in table-7 and the properties of concrete were tested on fresh and hardened concrete and result are given in table-12 & 13 and graphical representation have also been provided in fig. 1,2&3.

Table-12

Compressive Strength Test Result on G.W.F. & C.S.								
Cube ID	Weight (kg)	Slump	7 Days			28 Days		
			Avg. Load (KN)	Strength (Mpa)	% increase in strength	Avg. Load (KN)	Strength (Mpa)	% increase in Strength
N	8.365	100	506.3	22.505		723.38	32.15	
MIX-1	8.468	85	563.693	24.3372	8.14%	805.28	35.79	11.22%
MIX-2	8.477	80	560.7	23.852	5.99%	801	35.6	10.73%
MIX-3	8.45	75	528.885	21.827	-3.02%	755.55	33.58	4.44%
MIX-4	8.353	73	524.003	20.9601	-6.86%	748.58	33.27	3.48%

Table-13

Split Tensile Strength Test on G.W.F. & C.S.					
Cube ID	Weight (Kg)	Slump	Average Load (KN)	Split Tensile Strength (Mpa) (28 Days)	% increase in strength
N	13.1	100	283.31	4.01	
MIX-1	13.3	85	368.09	5.21	29.92%
MIX-2	13.3	80	345.48	4.89	21.94
MIX-3	13.3	75	284.72	4.03	0.50%
MIX-4	13.1	73	276.24	3.91	-2.49%

Fig-1 Compressive Strength Graph

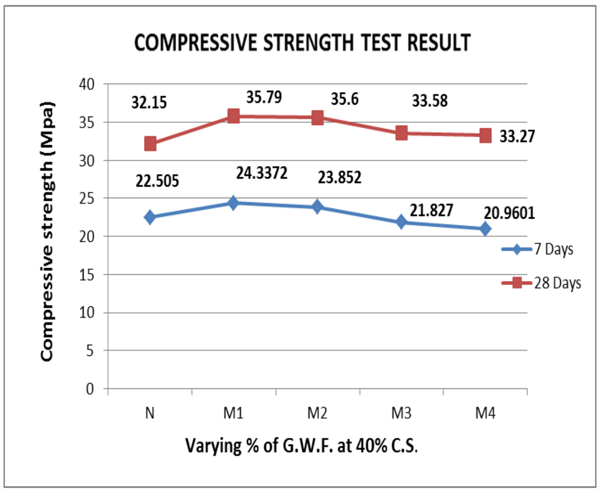


Fig-2 Split Tensile Strength Graph

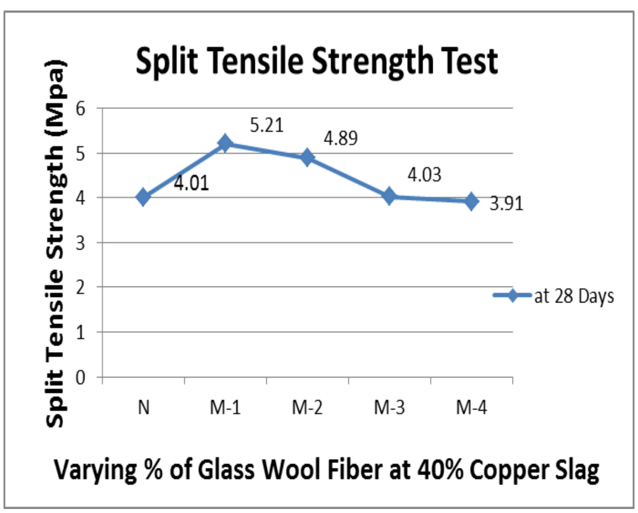
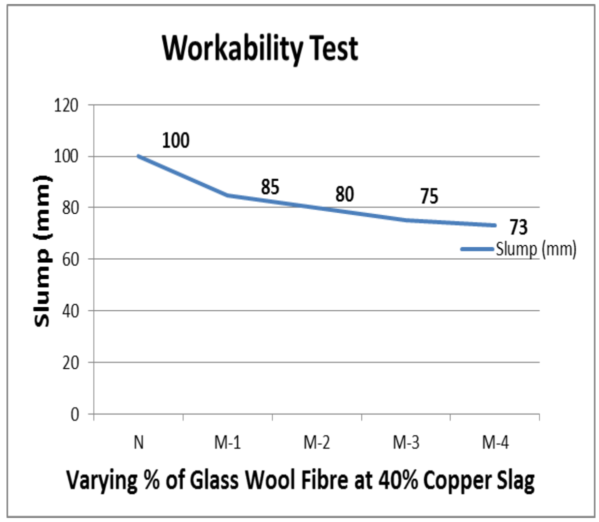


Fig-3 Slump Test Graph



4. RESULT AND DISCUSSION

By performing the experiment on Copper Slag, Glass Wool Fibre and combination of G.W.F. and C.S. it was observed that density of concrete increases with increase in C.S. percentage by 5-6%. This is probably due to the higher specific gravity of copper slag (3.68). There is significant increase in the compressive strength of concrete due to the addition of copper slag in suitable proportions up to a optimum percentage by weight of sand. The compressive strength has increased to a maximum of 11% with 40% replacement of fine aggregate by copper slag. However the effect on workability significant split tensile strength was increased by 8.5% at 40% of F.A. replacement as for control mix. On the other hand with use of G.W.F. density of concrete reduces as compared to control mix 3-4% and balling occurs at 1% addition it also have impact on compressive and split tensile strength at 0.2% of addition of total weight on concrete.

In the last phase of experiment when we have experimented on the combination of C.S. and G.W.F. it was observed that 0.8% addition of G.W.F. density reduces as compared to control mix and workability also reduces but there is an increase in strength in concrete as compared to control mix.

5. CONCLUSION

Addition of C.S. increases the density of concrete hence increases the self-weight of concrete.

The results shown by compressive strength test and split tensile strength test were improved by 11% and 8.73 % respectively at 40% replacement of F.A. by C.S.

At 40% replacement of C.S. workability was reduced by 20mm on slump cone test.

The best percentage of replacing C.S. is 40% witch give best result.

G.W.F. addition have a great impact on workability as it gets reduced on higher percentage but at0.2% it get reduced by 8mm

G.W.F. addition gives best result as compared to control concrete at 0.2% in terms of compressive strength and split tensile strength by 6% and 10% respectively. But the addition of higher percentage reduces the strength parameter.

When the test was conducted on combination of both C.S. & G.W.F. as given in table-7 we have observed increase in split tensile strength and compressive strength as compared to control mix. Workability of concrete was reduced on increasing percentage of G.W.F.

It was found at 0.2% addition of G.W.F. and at 40% replacement of F.A. by C.S. split tensile strength increased by 29.92 % and Compressive strength was increased by 11.22%. For 0.2% of G.W.F. workability was reduced by 15mm when performed by slump cone test.

Recommended percentage of addition of G.W.F. and F.A. replacement by C.S. is 0.2% and 40% respectively.

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