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EXPERIMENTAL STUDY ON GREEN CONCRETE WITH BASALT FIBER

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Abstract*— In this modern world, building structures have their own requirements in terms of design and durability. To satisfy this requirement of the structural integrity of each structure, modification of traditional cement concrete has become mandatory. plain concrete (PC) is a fragile material with low tensile strength and may crack under traction. Randomly distributed basalt fibers can bind these cracks and hinder their development. Copper smelting is an industrial by-product obtained during copper slag increase the workability of concrete. Green concrete is concrete which uses waste material as at least one of its components, which does not lead to environmental destruction or it has high performance and life cycle sustainability. This experimental work was conducted on concrete samples containing cut basalt fiber as replacement by weight of cement in concrete and copper slag as a partial replacement of a fine aggregate by copper slag at 10% 20%, 30%, 40% and 50% by weight. The standard cube measure the compressive strength after 7 days, 14 days and 28 days and water absorption test and cost compared this to that of control mixes of M25 grade.

***Keywords*— Basalt Fiber, Copper Slag, Cost, Compressive strength, Green Concrete, Environment, Water Absorption.**

I. INTRODUCTION

Concrete is the material of the construction industry, which is widely used around the world. It's universal, has desirable technical properties produced from cost effective materials that can be molded in any form that to fragile character. More than ten billion tons of concrete are consumed each year. Based on global usage, it has been placed in second position next to the water. The word "concrete" comes from the Latin word "concretus", whose meaning is compact or condensed. The main ingredients, such as sand fine aggregate and coarse aggregate, cement are used as binder and water is used to make concrete. Sometimes additives are used to modify various concrete properties, such as boosters, retarders, water reducers, high-end gears, etc. Modern developments in the field of concrete as Fiber Reinforced Concrete (FRC), High-Strength Concrete (HSC), Self-Compacting Concrete (SCC), Autoclaved Aerated Cellular Concrete (ACA), High Strength Concrete (HPC), Reactive Powder Concrete (RPC), Ultra High Productive Concrete (UHPC) , Light Concrete, Permeable Concrete, Composite Concrete, Etc.

If this is a requirement of structural integrity for each structure, modification of traditional cement concrete has become mandatory. Plain concrete (PC) is a brittle material with low tensile strength. Therefore, the PC is most likely cracking under tensile stress. It was found that adding different types of fibers to concrete with the percentage improves the chemical and mechanical properties, durability and service criteria of the structure. The study concluded that basalt fibers are easily mixed with concrete without the formation of balls or segregation. In addition, there is the increase in energy absorption capacity after cracking and the increase in impact resistance were also noticeable. When mixed in concrete, randomly distributed fibers can fill these cracks and stop their development. By this mechanism is well established that adding fibers can improve the mechanical behavior of the Plain Concrete.

For any construction industry, concrete is a composite material composed of cement, fine aggregates and coarse aggregates. Essential Requirements fine aggregates are the main material used in the manufacture of mortar and concrete and are very susceptible preparation of the design of the mixture. The use of natural sand is high because of the widespread use of concrete and mortar. So the demand for in developing countries, natural sand is very high to meet the rapid growth of infrastructure. Some other materials have has already been used as a substitute for natural sand, such as quarry dust, ashes and silica powder, limestone and filtered sand is used in concrete and mortar mixtures as a partial or total replacement for natural sand.

II. EXPERIMENTAL MATERIALS

a) Basalt fiber:

They are generally in the form of continuous monofilament or in the form of chopped length. The other forms are like basalt mesh, basalt rod, etc. They have high toughness and modulus of elasticity and also high temperature resistance capacity. For this research work the basalt chopped fiber strands of having 12 mm length and 1 μm diameters were taken.

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The following figure 1 shows the basalt fiber.

Figure 1 Basalt Fiber

Following table 1 show the physical properties of basalt fiber and table 2 shows chemical properties of cement which is compared to chemical properties of basalt fiber.

Table 1 Physical Properties of Basalt Fiber

Physical Properties	Results
Density	2500 kg/m^3 - 2800 kg/m^3
Modulus of elasticity	89 Gpa
Stability at tension (after thermal treatment) %	20º C – 100% 200º C – 95% 400º C – 82%

(Source: Nickunj extimp enterprise ltd., Mumbai, India)

Table 2 Chemical Properties of Basalt Fiber

Chemical Properties	Results	
	Cement	Basalt Fiber
SiO_2	19.71	69.51
Al_2O_3	5.20	14.18
Fe_2O_3	3.73	3.92
CaO	62.91	5.62
MgO	2.54	2.41
K_2O	0.90	1.01
Na_2O_3	0.25	2.74

(Source: Nickunj extimp enterprise ltd., Mumbai, India)

b) Copper slag:

Copper slag (CS) is an industrial waste generated in huge amount from copper industries and can be exploited as a potential substitute to river sand in concrete production. The CS is obtained as by-product from copper metal either as dense CS or granulated CS depending upon the method of cooling of molten slag discharge from the furnace. The molten slag solidified by pouring into the water results in granulated CS whereas gradually air cooled slag form the dense CS. It was estimated that to yield 1 ton of copper, about 2.2–3 tons of CS is generated as a by-product.

The following figure 2 shows the copper slag.

Figure 2 Copper Slag

Following table 3 shows the physical properties of copper slag and table 4 shows chemical properties of cement which is compared to chemical properties of copper slag.

Table 3 Physical Properties of Copper Slag

Physical Properties	Results
Zone of Copper slag	II
Fineness Modulus of copper slag	3.5
Water Absorption (%)	1.1
Sp. Gravity	3.59
Silt Content in % (finer than 75 μ)	6.0

(Source: Modi Laboratory, Ahmedabad, Gujarat)

Table 4 Chemical Properties of Copper Slag

Chemical Properties	Results	
	Cement	Copper Slag
Al_2O_3	5.20	2.97
TiO_2	-	0.54
Fe_2O_3	3.73	51.67
SiO_2	19.71	41.10
CaO	62.91	0.18
MgO	2.54	0.56
K_2O	0.90	1.12
Na_2O	0.25	1.05
Cu	-	0.65
Specific Gravity	3.15	3.57
Conductivity	-	4.95

(Source: Modi Laboratory, Ahmedabad, Gujarat)

c) Cement:

Cement is a binder used in construction that hardens, hardens and adheres to other materials in order to bind them. Cement is rarely used alone, but rather to bind fine aggregate and coarse aggregate. Cement mixed with fine aggregates produces masonry mortar or sand and gravel for the production of concrete. Cement is the most used material that exists and is only for water, the most consumed resource on the planet.

Table 4 shows the chemical properties of cement.

d) Fine Aggregate and Coarse Aggregate:

Those fractions from 4.75 mm to 150 micron are termed as fine aggregate. Locally available sand, free from silt and organic matters was used. The river sand is be used in combination as fine aggregate conforming to the requirements of IS 383- 1970.

Coarse Aggregate is crushed granite metal with 60% passing 20 mm and retained on 12.5mm sieve and 40% passing 12.5mm and retained on 4.75mm sieve were used. The weight of coarse aggregate was 60% of the total aggregate and specific gravity of coarse aggregate was 2.84.

Table 5 Properties of Fine Aggregate and Coarse Aggregate

Property	Fine Aggregate	Coarse Aggregate	
		20 mm	10 mm
Specific Gravity	2.65	2.84	2.78

III. Experimental Methodology

The following mix design was used in proposed research work.

a) Design Mix Properties

The following table 6 shows design mix properties in 1 m^3 concrete.

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Table 6 Design Mix Properties in 1m^3 concrete (kg)

Concrete mixes	Design mix for concrete					
	Cement	Fine Aggregate	Coarse Aggregate	Water	Copper Slag	Basalt Fiber
A1	436.00	690.69	1127.36	191.60	0.00	0.00
B1 (CS-10%)	436.00	621.63	1127.36	191.60	69.06	0.00
B2 (CS-20%)	436.00	552.56	1127.36	191.60	138.13	0.00
B3 (CS-30%)	436.00	483.49	1127.36	191.60	207.20	0.00
B4 (CS-40%)	436.00	443.49	1127.36	191.60	247.20	0.00
B5 (CS-50%)	436.00	414.42	1127.36	191.60	276.27	0.00
C1 (CS-40%,BF-0.5%)	433.82	443.49	1127.36	191.60	247.20	2.18
C2 (CS-40%,BF-1%)	431.64	443.49	1127.36	191.60	247.20	4.36
C3 (CS-40%,BF-1.5%)	429.46	443.49	1127.36	191.60	247.20	6.54

b) Compressive Strength Test (IS 512:1956)

Concrete cubes of 150 mm × 150 mm × 150 mm are casted by using M25 grade concrete. The compression strength test is carried out on the specimens at the end of 7 days, 14 days and 28 days of curing.

Compressive Strength = Load / Cross-sectional Area

The following figure 3 shows setup of compressive strength testing machine

Figure 3 Setup of Compressive Strength Testing Machine

c) Water Absorption Test (IS 2185 Part 1:2005)

Standard size concrete blocks shall be completely immersed in clean water at room temperature for 24 hours. All concrete blocks shall be dried in a ventilated oven at 100 to 115^{0}C for not less than 24 hours.

Absorption, percent = (W1-W2)/W2 * 100

Where, w1=wet mass of unit (kg)

w2= dry mass of unit in (kg)

The following figure 4 show the water absorption of concrete cubes.

Figure 4 Water Absorption Test

IV Experimental Result and Discussion:

From following different test result shown below:

a) Compressive strength test results:

Following table 7 shows compressive strength at 7, 14 and 28 days.

Table 7 Compressive Strength at 7, 14 and 28 days

Concrete Mixes	Compressive Strength (N/mm^2)		
	7 days	14 days	28 days
Control Mix Concrete			
A1	19.41	24.30	29.93
Copper Slag Replaced with Fine Aggregate			
B1 (10%)	24.15	28.59	32.74
B2 (20%)	24.51	29.93	33.33
B3 (30%)	25.04	30.22	34.22
B4 (40%)	27.41	32.15	35.26
B5 (50%)	22.81	27.70	29.33
Concrete with Basalt Fiber and Copper Slag			
C1 (0.5%BF+40%CS)	29.78	32.30	34.96
C2 (1%BF + 40%CS)	29.48	33.04	35.70
C3 (1.5%BF+40%CS)	30.52	35.11	36.89

In B batch of green concrete mixes with replacement of sand by copper slag, B4 mix made with 40% replacement of copper slag shows 35.26 N/mm^{2}compressive strength and control mix concrete A1 shows 29.93 N/mm^2 both after 28 days. In C batch of concrete mixes with replacement of cement by basalt fiber, C3 mix shows 36.89 N/mm^2 compressive strength and control mix concrete A1 Mix shows 29.93 N/mm^2 both after 28 Days.

Following figure 5 shows the compressive strength for M25 mixes: Control mix concrete and concrete with replacement of copper slag and basalt fiber in different proportions at 7, 14 and 28 days

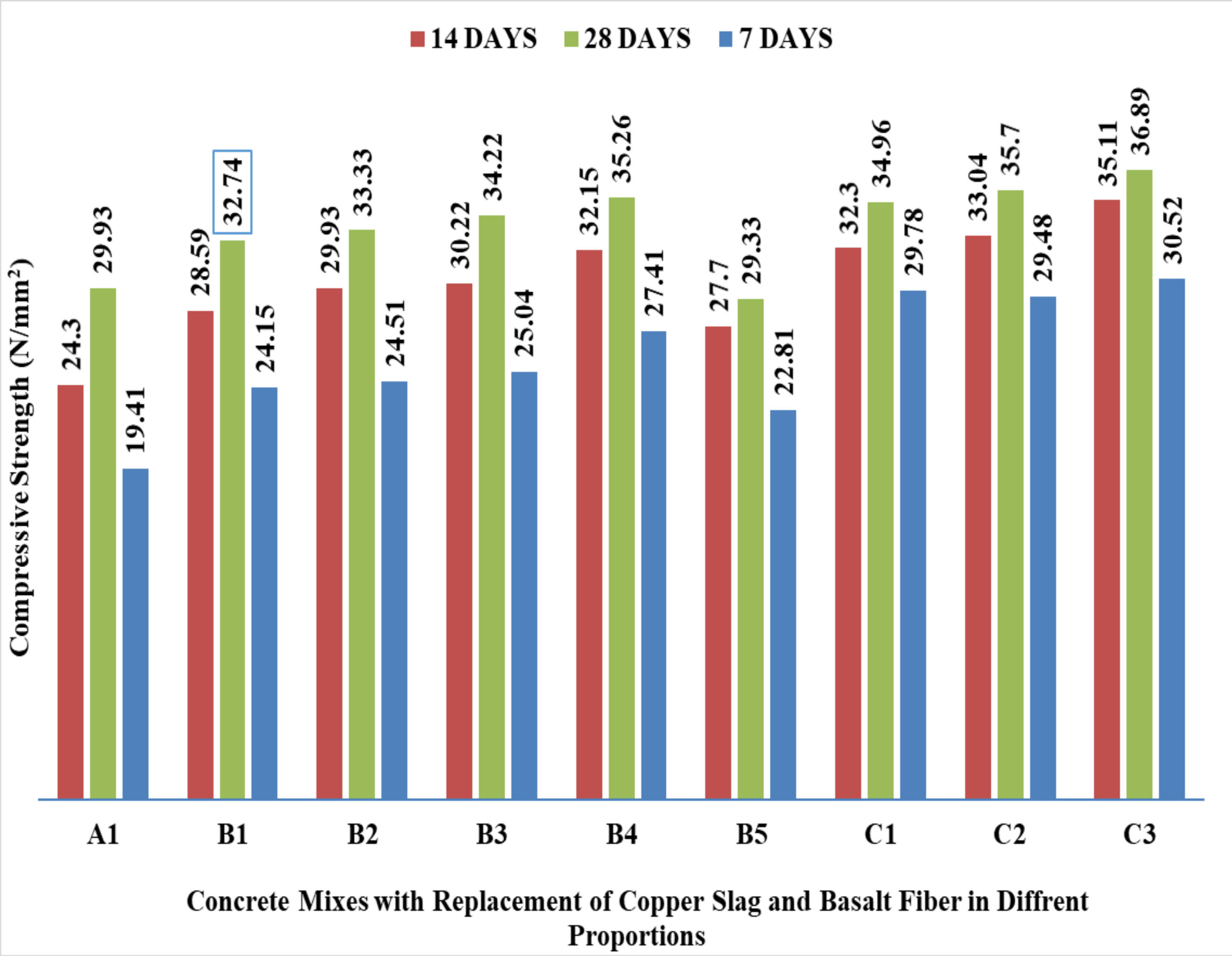

Figure 5 Compressive Strength Results for M25 Concrete Mixes: Standard Concrete and Concrete with replacement of copper slag and basalt fiber in Different Proportions at 7, 14 and 28 days

From above figures 5, it can be said that compressive strength of the M25 grade of Concrete mixes with copper slag and basalt fiber increased with increase in days. Also compressive strength increases with increase in Proportions of copper slag in concrete content up to 40% copper slag and 1.5% basalt fiber as compared control mix Concrete Mix A1.

b) Water Absorption Test Results:

Following table 8 shows the results of percentage water content immersed in cubes for the water absorption test done on concrete cubes at 28 days for M25 concrete mixes control mix concrete and concrete with replacement with copper slag and basalt fiber in different proportions.

Table 8 Water Absorption Test Results for M25 Concrete Mixes: control mix Concrete and Concrete with replacement of Copper Slag and Basalt Fiber in Different Proportions at 28 Days

Concrete Mixes	24 Hour Saturation Weight (W1) (Kg)	Oven Dry Weight (W2) (Kg)	Water Absorption (%)
A1	8.44	8.67	2.72
B1 (10% CS)	8.42	8.64	2.61
B2 (20% CS)	8.30	8.52	2.65
B3 (30% CS)	8.31	8.53	2.64

B4 **(40% CS)**	8.45	8.66	2.48
B5 **(50% CS)**	8.38	8.58	2.38
C1 **(0.5%BF+40%CS)**	8.36	8.54	2.15
C2 **(1% BF+40% CS)**	8.32	8.49	2.04
C3 **(50% BF+40%CS)**	8.50	8.66	1.88

Following figure 6 shows percentage water absorbed in control mix concrete and Concrete with replacement of copper slag and basalt fiber in different proportions.

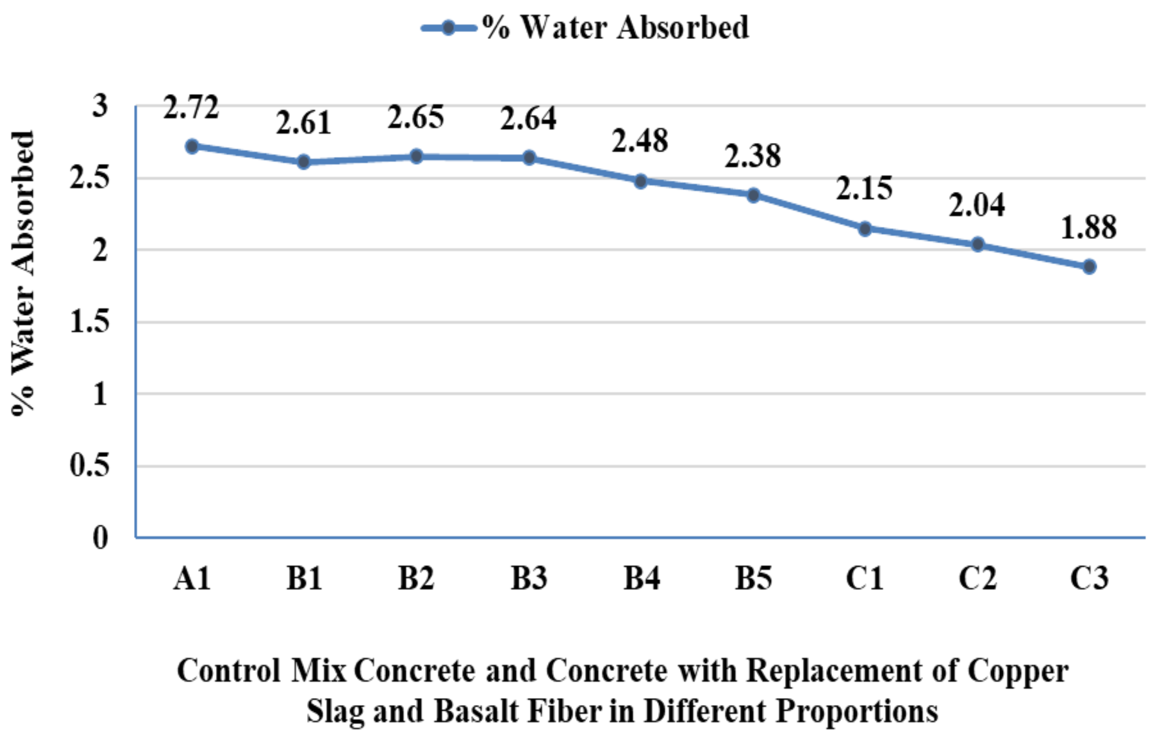

Figure 6 Percentage Water Absorbed for M25 Concrete Mixes: Standard Concrete and Concrete with Replacement of Copper Slag and Basalt Fiber in Different Proportions

From above figure 6, it can be said that for Concrete mixes percentage water absorbed was decreases with increase in copper slag and basalt fiber in concrete content up to 40% and 1.5 % respectively compared to control mix Concrete Mix A1.

IV. **Cost Analysis:**

Following table 9 shows the rate analysis as per different quantity of items as per current market rates for various concrete mixes.

Table 9 Cost of Materials

Materials	Cost Rs./kg
Cement	6.00
Fine Aggregate	060
Coarse Aggregate	0.65
Copper Slag	0.20
Basalt Fiber	600

Table 10 Total Cost of Concrete Mixes for 1 m^3 with Replacement of Copper Slag and Basalt Fiber in Different Proportions

Concrete Mixes	Cost of material of Concrete/ m^3	% Change in Cost of Concrete
A1	3763.20	0
B1 (10% CS)	3735.57	(-) 0.74
B2 (20% CS)	3707.95	(-) 1.48
B3 (30% CS)	3680.32	(-) 2.20
B4 (40% CS)	3664.32	(-) 2.63
B5 (50% CS)	3652.69	(-) 2.94
C1 (0.5% BF+40% CS)	4959.24	(+) 31.78
C2 (1% BF+40% CS)	6254.16	(+) 66.19
C3 (1.5% BF+40% CS)	7549.08	(+) 100

Following figure 7 shows the rates for M25 Concrete Mixes: Standard Concrete and Green Concrete with Inclusion of Basalt Fiber in different proportion for 1 m^3 concrete.

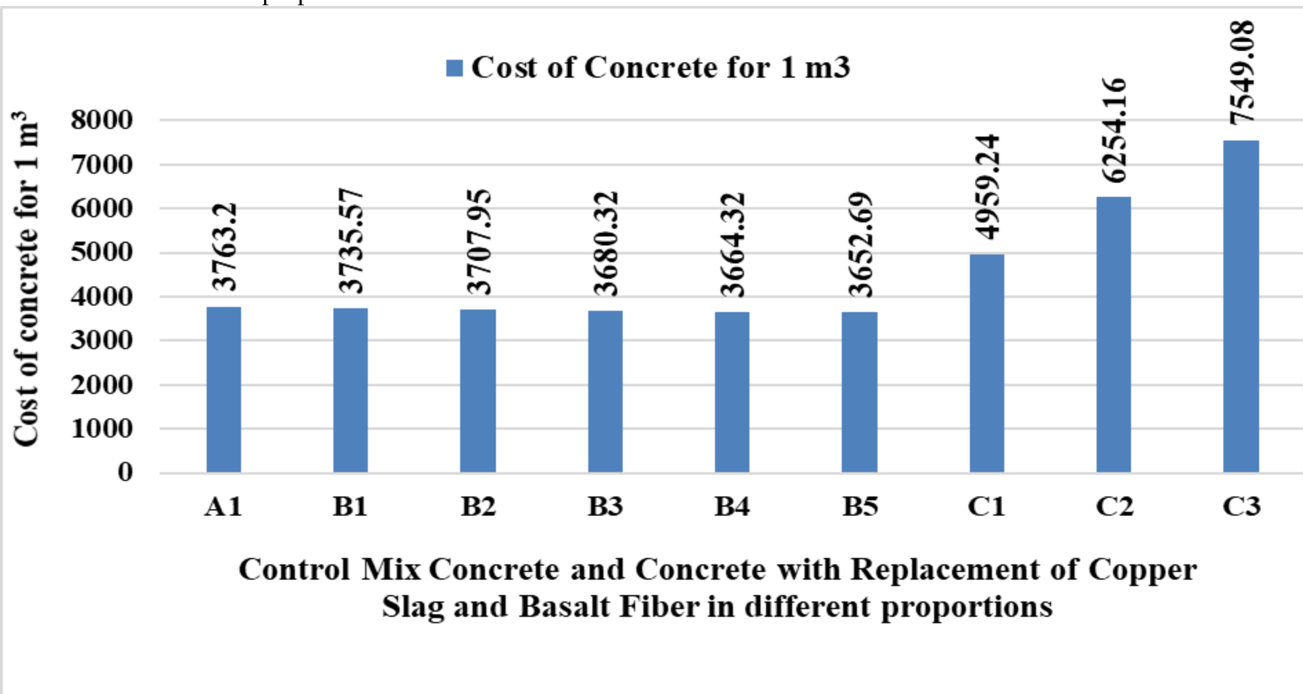

Figure 7: Total Cost of Concrete for 1 m^3 M25 Concrete Mixes

From above figure 7, it can be said that Green Concrete mixes with Inclusion of Copper Slag in different proportion have lower rates for 1 m^3 concrete with compared to Control Mix Concrete A1. Rates of Green Concrete increase with increase in basalt fiber proportion.

V. CONCLUSION

Based on experimental investigations concerning compressive strength, water absorption and rate analysis for control mix concrete and green concrete with basalt fiber in different proportions mixes the following conclusions are drawn out for different parameters.

1. Compressive strength of green concrete was increasing by replacement of copper slag in different proportion for concrete mixes as compared to control mix concrete.
2. Concrete mixes made content up to 40% replacement of copper slag gives more compressive strength of 28 days compare to control mix concrete.
3. In c batch of concrete mixes with basalt fiber and copper slag, C3 mix made with 40% replacement of copper slag and 1.5% basalt fiber shows 36.89 N/mm^2 compressive strength and control mix concrete A1 mix shows 29.93 N/mm^2 both after 28 days. In B batch of concrete mixes with replacement of copper slag, B4 mix shows 35.26 N/mm^2 compressive strength and control mix concrete A1 mix shows 29.93 N/mm^2 both after 28 days.
4. Concrete mixes which are made with replacement of copper slag and basalt fiber in different proportion gives acceptable compressive strength results. So that all Concrete mixes have excellent compressive strength and are suitable for structural applications.
5. Percentage water absorption of concrete was decreasing by increasing replacement of copper slag and basalt fiber in different proportion for concrete mixes as compared to control mix concrete mix. The lower water absorption was observed in concrete mix with replacement compared to Control Mix Concrete.
6. In B batch of concrete mixes with replacement of copper slag, B1, B2, B3, B4 and B5 mix shows 2.61%, 2.65%, 2.64%, 2.48%, 2.38% respectively water absorption and control mix concrete A1 mix shows 2.72% water absorption both after 28 days. In C batch of concrete mixes with replacement of basalt fiber C3 mix shows 1.88%water absorption and control mix concrete A1 shows 2.72% water absorption both after 28 days.
7. The water absorption of green concrete with basalt fiber showed lower water absorption when compared to control mix concrete.
8. Green concrete mixes with replacement of copper slag in different proportion have lower rates for 1 m^3 concrete with compared to control mix concrete A1.
9. Rates of concrete increases with increases in basalt fiber content in the concrete compared to control mix concrete.
10. Based on the cost calculations, it can be concluded that savings in cost can be attained in the production of green concretes of with only replacement of copper slag.

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