Experimental Studies on Replacement of Fine Aggregate by Copper Slag and Replacement of Cement by Sugarcane Bagasse Ash in Concrete

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Abstract: Copper slag is a by-product of copper industry and sugarcane bagasse ash is a by-product of sugar cane industry and using them in concrete proves to be economical and environmentally friendly. The fine aggregate was replaced by copper slag of about 35%, 40%, 45% and 50%. The optimum content was found with the copper slag replacement as 40% and then the sugarcane bagasse ash was replaced with 5%, 10% and 15%. The result showed that it has properties similar to natural aggregate and it does not cause any harm if incorporated into concrete. A comparison is made between normal concrete with percentage of copper slag and sugarcane bagasse ash replacement. Compressive strength and split tensile strength for concrete with that of the conventional concrete. The strength of the concrete was found to be high when the copper slag replaced was 40% and sugarcane bagasse ash replacement was replaced by 5% in M30 grade concrete which was found to be the optimum value.

Keywords: Copper slag, Bagasse ash, Compressive strength, Tensile strength

I.INTRODUCTION

Concrete is the single widely used construction material in the world today. It is used in buildings, bridges, sidewalks, highway pavements, house construction, dams and many other applications. The key to a strong and durable concrete are the mix proportions between the various components. Less cement paste can lead to more voids, thus less strength and durability while more cement paste can lead to more shrinkage and less durability. The gradation and the ratio of fine aggregates to coarse aggregates can affect strength and porosity of concrete. The mix design should achieve the desired workability of concrete so as to prevent segregation and allow for ease of placement. Typically, a concrete mix is about 10% to 15% cement, 25% to 30% sand, 40% to 45 % aggregates and 15% to 20% water. Concrete should have enough compressive strength and flexural strength to support applied loads. At the same time it should have good durability to increase its design life and reduce maintenance costs. In general, durable concrete will have good resistance to freeze and thaw, abrasion, sulphate resistance, ultraviolet radiation, seawater, alkali-silica reaction and chlorides. The gradation and maximum size of aggregates are important parameters in any concrete mix. They affect relative proportions in mix, workability, economy, porosity and shrinkage of concrete. Copper slag a waste which is obtained during the extraction of copper from the copper ore is to be replaced as a material in fine aggregate in concrete. The copper slag is varied in percentages in the concrete so that the maximum strength available for the maximum percentage of copper slag is found.

II. OBJECTIVE

- To recycle the copper slag particles so that the land pollution is minimised.
- To ensure there is no scarcity in the river sand for future generation.
- To reduce the self-weight of concrete and make the concrete more economic.
- To conduct test for the fresh and hardened concrete for the designed proportion of coppers slag and SCBA .

III LITERATURE REVIEW

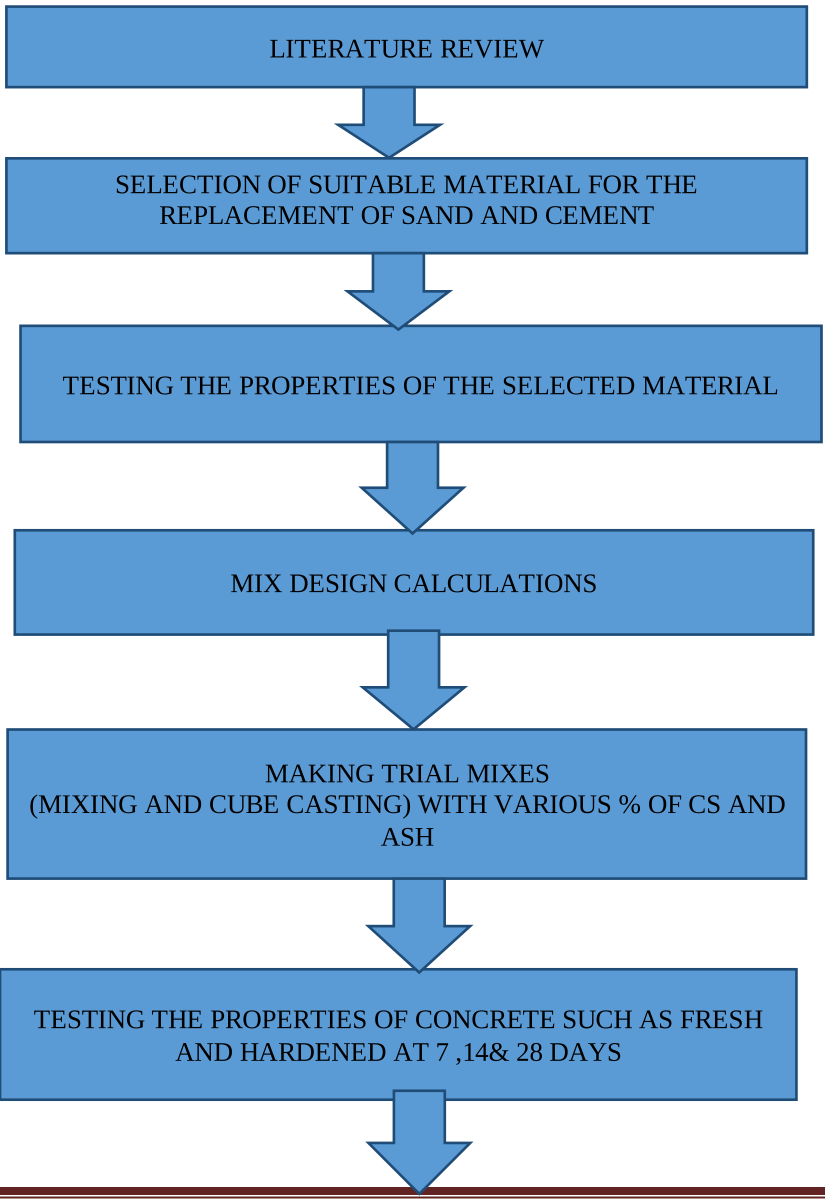
*A.Gowshik et al (2015)*the copper slag is used as a replacement of fine aggregate in M40 concrete and the strength of the concrete was determined for the concrete on 7, 14 and 28 days. In this experiment study, copper slag was replaced from 0-50% of fine aggregate. It is observed that for all the percentage of replacement of fine aggregate by copper slag the flexural strength of concrete is more than the control mix.

Brittany Radke 2012, who described thatBrazil has been mass producing ethanol from sugarcane since 1970's. Ethanol accounts for over 50% of the fuel used in passengers cars. Sugar is extracted from sugarcane. Similarly bagasse is burned to produce energy and steam for power. After burning, ash only remains. In brazil approximately 2.5 million tons of sugarcane bagasse ash are produced in each year. Aggregates acts as fillers while the cement and water are the binders that hold everything together. Manufacturing of Portland cement accounts for 5% of the world carbon emission. High silica content: 87%.Low specific gravity 1.80. Percentage passing 45 micron is 95%

Tamil Selvi.P et al (2014) the effect of concrete using copper slag as fine aggregate replacement. In this project work the concrete grade M40 was selected and IS method was used for the mix design. The properties of material used in the concrete including the copper slag which was used in the mix design was studied. The various strength of concrete like compressive, flexural and split tensile were studied and NDT were studied for the various replacement of fine aggregate by copper slag that are 0,20,40,60,80,100%. The maximum compressive strength of concrete attained at 40% replacement of fine aggregate at 7 and 28 days. The split tensile strength and the flexural strength were also obtained higher strength at 40% replacement level at 28 days. The rebound hammer test showed higher compressive strength at 40% fine aggregate replacement, this was due to the uniformity in the concrete.

Suresh Reddy et al (2013) concrete made of copper slag replacing sand up to 50% are used to study the strength parameters, compressive strength, split tensile strength and flexural strength of both M30 and M40 concrete mixes. Sand was replaced with copper slag in proportions of 0, 10, 20, 30, 40, and 50%.

III. METHODOLOGY



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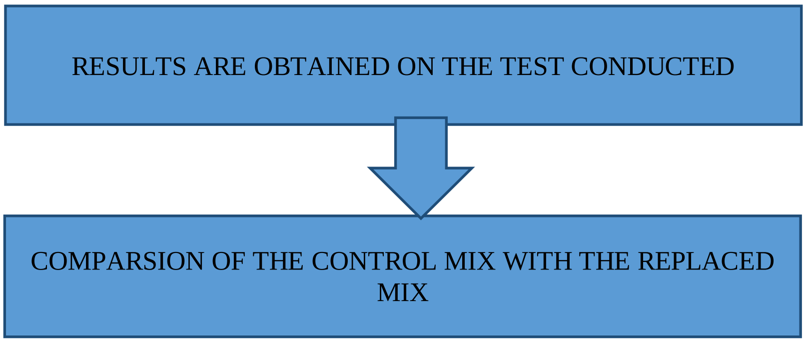


IV. MATERIAL INVESTIGATION

1 Cement

The cement used should confirm IS specifications. There are several types of cements available commercially in the market of which Portland cement is very common and it is well known and available everywhere. PPC 43 grade was used for this study. The physical properties of the cement tested according to standard procedure confirm to the requirement of IS 1489 Part 1. The physical properties of the cement are listed in the table 1

Table1 Physical Properties of Cement

S.No	Characteristics	Value Obtained experimentally
1	Standard Consistency	30%
2	Fineness of cement as retained on 90 micron sieve	5%
3	Initial setting time	30 minutes
4	Specific gravity	3.15

2 Fine Aggregate

Locally available river sand passing through 4.75mm sieve conforming to the recommendation of IS 383:1970 is used. Specific Gravity of fine aggregate is found and the particle size distribution is listed below in the Table 2

Table2 Particle Size distribution for fine aggregate

Weight of fine aggregate = 3000 grams

Sieve Size	Weight Retained (grams)	Cumulative percentage retained	Cumulative percentage passing
4.75mm	75	2.50	97.50
2.36mm	100	5.83	94.17
1.18mm	150	10.83	89.17
600micron	200	17.50	82.50
300micron	500	34.16	65.84
150micron	840	62.16	37.84
75micron	455	77.33	22.67
Pan	680	100	0

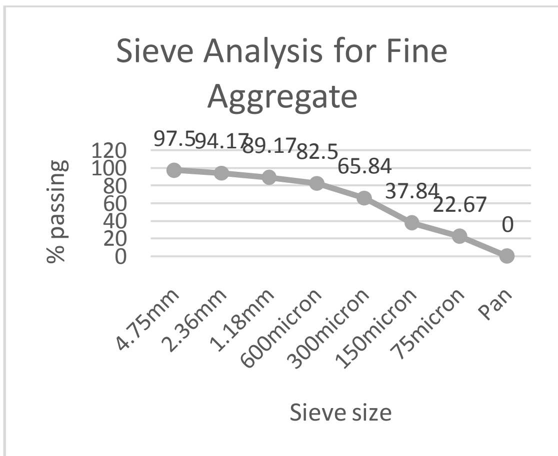


Figure 1 Sieve Analysis for Fine Aggregate

From the sieve analysis results fine aggregate is graded to Zone IV

3 Coarse Aggregate

Coarse aggregate to be used for production of concrete must be strong, impermeable, durable and capable of producing a sufficient workable mix with minimum water cement ratio to achieve proper strength. Locally available coarse aggregate retaining on 4.75 mm sieve is used. Specific Gravity of coarse aggregate was found and the particle size distribution for coarse aggregate is listed below in Table 3

Table 3 Particle Size Distribution for Coarse Aggregate

Weight of coarse aggregate = 3000 grams

Sieve Size	Weight Retained (grams)	Cumulative percentage retained	Cumulative percentage passed
40mm	0	0	100
20mm	100	3.33	96.67
16mm	600	23.33	76.67
12.5mm	750	48.33	51.67
10mm	800	75.00	25.00
4.75	750	100	0

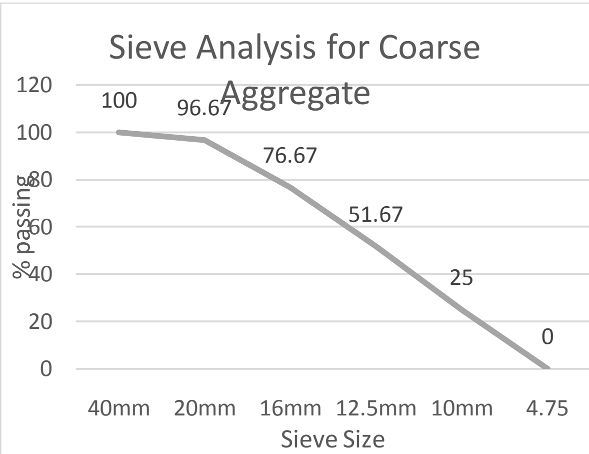


Figure 2 Sieve Analysis for Coarse Aggregate

From the sieve analysis results nominal size of coarse aggregate is 20mm

4 Water

The quality of mixing water for concrete has a visual effect on the resulting hardened concrete. Impurities in water may interfere with the setting time of cement and will adversely affect the strength and durability of concrete with copper slag. Fresh and clean water which is from organic matter silt, oil, and acid material as per standards is used for casting the specimens. Water that is piped from the public supplies is used.

5 Copper slag

Copper slag is a by-product of copper extraction by smelting. During smelting, impurities become slag which floats on the molten metal. Slag that is quenched in water produces angular granules which are disposed of as waste or utilized are used in construction. Copper slag is an irregular black, glassy and granular in nature and its properties are similar to sand. In this project copper slag used is brought from Sterlite Industries India Ltd, Tuticorn. Every ton of copper will generate approximately 2.2-3 tons of copper slag.

Table 4 Chemical Composition of Copper Slag

S.No.	Chemical Components	% of Chemical Component
1.	Fe_2O_3	68.29
2.	SiO_2	25.84
3.	LoI	6.59
4.	Al_2O_3	0.22
5.	CaO	0.15
6.	Na_2O	0.58
7.	K_2O	0.23
8.	Mn_2O_3	0.22
9.	TiO_2	0.41
10.	SO_3	0.11
11.	CuO	1.20
12.	Insoluble residue	14.88
13.	Chloride	0.018
14.	Others	0.25

6 Sugarcane bagasse ash

Bagasse ash is a fibrous matter that remain after sugarcane or sorghum stalks are crushed to extract their juice. It is used as a biofuel and in the manufacture of pulp and building materials.After crushing of sugarcane in sugar mills and extraction of juice from processed cane by milling, the discarded fibrous matter is called bagasse. Bagasse is burnt around 500^{o}C in a controlled process to use its maximum fuel value. The residue after burning, namely bagasse ash is collected using bag-house filter. Bagasse ash is directly disposed to the nearest land as a slurry. In spite of being a material of hard degradation and that presents few nutrients, the ash is used on the farms as a fertilizer in the sugarcane harvests. In this sugarcane bagasse ash was collected during the cleaning operation of a boiler operating in the ERAIYUR SUGAR FACTORY, located in Pennadam (Cuddalore), Tamilnadu. The various chemical composition of bagasse are listed

Table 5 Chemical Composition of Bagasse

S.NO	COMPONENT	MASS (%)
1	Silicon Dioxide(SiO_2)	78.34
2	Aluminium (Al_2)	8.55
3	Ferrous Oxide(Fe_2O)	3.61
4	Calcium Oxide(CaO)	2.15
5	Na_2O	0.12
6	Potassium Oxide(K_2O)	3.46
7	Magnesium Oxide(MgO)	0.13
8	Titanium Oxide(TiO_2)	0.50
9	Barium(BaO)	<0.16
10	(P_2O_5)	1.07
11	Loss of Ignition	0.42

V. TEST ON MATERIALS

Table 6 Test results

MATERIALS	SPECIFIC GRAVITY	CONSISTENCY	FINENESS	IMPACT TEST
Cement	3.15	31%	5%	
Sugarcane Ash	2.12	28%	7%	
Copper slag	3.5			
Fine aggregate	2.65			
Coarse aggregate	2.65			6.20 %

VI CONCRETE MIX DESIGN

Mix design calculations

A.1 Target Strength for Mix Proportion

$f'_{ck} = f_{ck} + 1.65 \times S$

Where,

f'_{ck} = Target average compressive strength at 28 days

f_{ck} = Characteristic compressive strength at 28 days

S = Assumed standard deviation in N/mm^2 = 5 (as per table -1 of IS 10262-2009) = 30 + 1.65 x 5.0 = 38.25 N/mm^2

Percentage of CS replacement	Percentage of SCBA replacement	Cement Content Kg/m^3	Fine aggregate Kg/m^3	Coarse aggregate Kg/m^3	Copper slag Kg/m^3	SCBA Kg/m^3
35%	5%	415.82	446.73	1131.76	240.54	21.88
40%	10%	393.93	412.37	1131.76	274.90	43.77
45%	15%	372.05	378.0	1131.76	309.27	65.65
50%		437.7	343.63	1131.76	343.63	

A.2 Selection of Water – cement ratio

From table 5 of IS 456 the water cement ratio is adopted as 0.45

Hence w/c=0.45

A.3. Water Content

From table 2 of IS 10262 the maximum water content for 20mm aggregate is 186 litre

Water content = 197 litre

A.4 Cement Content

w/c ratio = 0.45

Therefore cement = 197/0.45 = 437.7 kg/m^3

A.5 Volume of Aggregates

From table 3 of IS 10262

Volume of coarse aggregate = 0.61

Volume of fine aggregate = 1-0.61=0.39

A.5 Mix Calculations

a) Volume of Concrete = 1 m^3
b) Volume of Cement = (437.7/3.15)/1000 = 0.138 m^3
c) Volume of water = 0.197 m^3
d) Volume of aggregate = 1-0.138-0.197 = 0.665 m^3
e) Mass of Coarse aggregate = 0.665*0.61*2.65*1000 = 1131.76 kg/ m^3
f) Mass of Fine aggregate = 0.665*0.39*2.65*1000 = 687.27 kg/ m^3

Cement	= 437.7 kg/ m^3
Water	= 197 kg/ m^3
Fine Aggregate	= 687.27 kg/ m^3
Coarse Aggregate	= 1131.76 kg/ m^3
Water Cement ratio	= 0.45

Table 7 Mix design

VII TEST ON CONCRETE

1 TEST ON FRESH CONCRETE

1.1 SLUMP CONE TEST

Table 8 Slump Cone test Values for CS replacement

Percentage of CS replacement	Slump Value in mm
Nominal Mix	95
35%	100
40%	100
45%	110
50%	115

The slump Cone test for the various percentage of SCBA replacement are as follows

Table 9 Slump Cone test Values for SCBA replacement

Percentage of SCBA replacement	Slump Value in mm
Nominal Mix	95
5%	110
10%	115
15%	120

1.2 COMPACTION FACTOR TEST

Table 10 Compaction Factor Values for CS replacement

Percentage of CS replacement	Compaction Factor value in %
Nominal Mix	0.92
35%	0.93
40%	0.95
45%	0.96
50%	0.96

The Compaction Factor test for the various percentage of SCBA replacement are as follows

Table 11 Compaction Factor Values for SCBA replacement

Percentage of SCBA replacement	Compaction Factor value in %
Nominal Mix	0.92
5%	0.95
10%	0.96
15%	0.96

Figure 3 Slump Cone test result for CS replacement

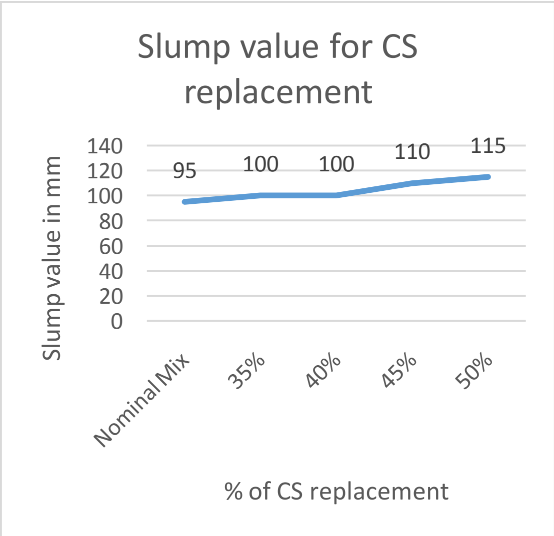
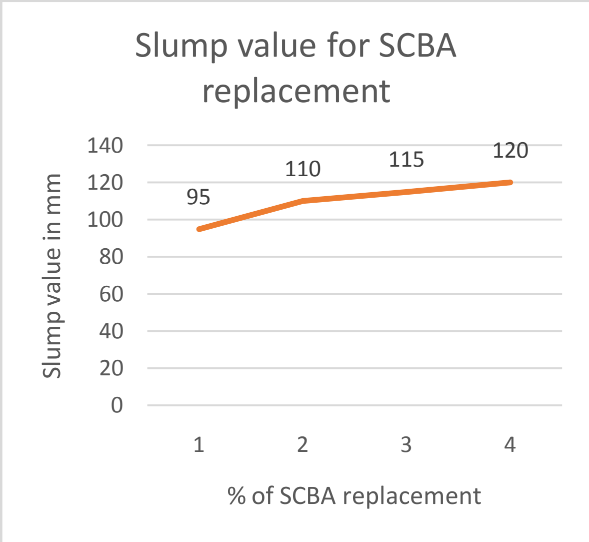


Figure 4 Slump Cone test result for SCBA



From the graph it is seen that the workability is increased due to the free water content because of less absorption water ratio of Copper slag.

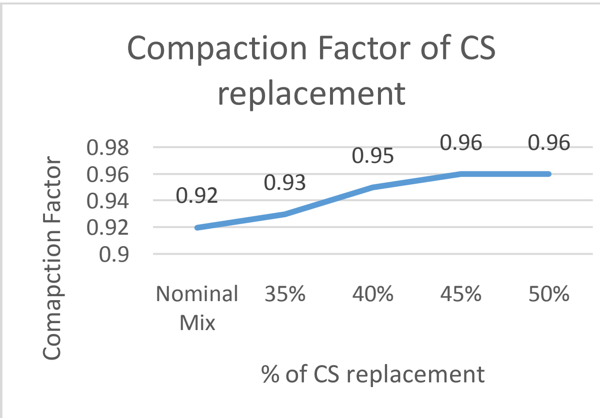


Figure 5 Compaction Factor of CS replacement

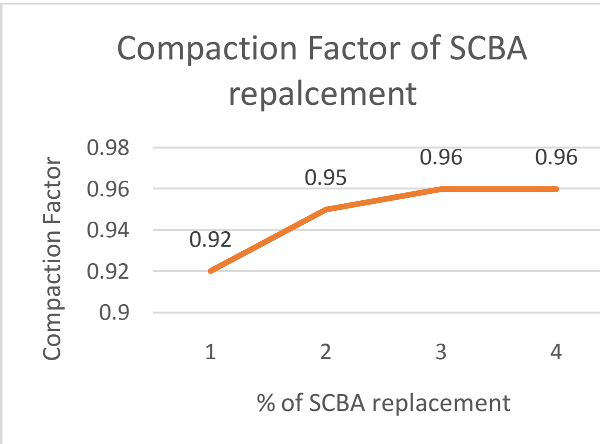


Figure 6 Compaction Factor of SCBA replacement

2 TEST ON HARDENED CONCRETE

2.1 COMPRESSIVE STRENGTH TEST

Table 12 Compressive strength Test on Conventional Concrete

Conventional Concrete	Compressive strength at 7 days N/mm^2	Compressive strength at 14 days N/mm^2	Compressive strength at 28 days N/mm^2
CS1	18.5	23.2	32.4
CS2	18.8	25.5	33.5

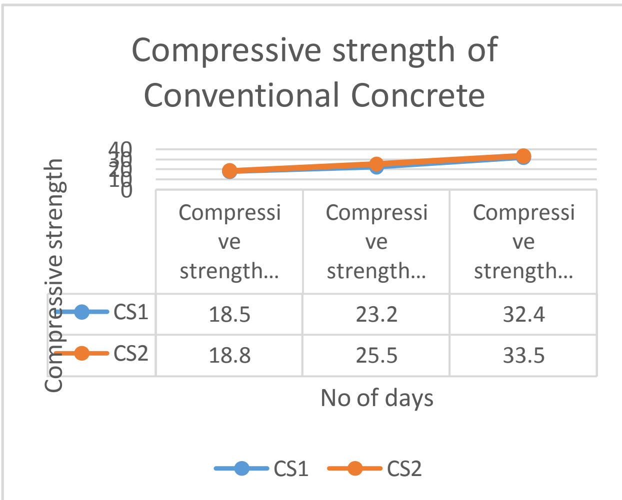
Table 13 Compressive strength Test on Copper Slag replacement

Percentage replacement of Copper Slag	Compressive strength at 7 days N/mm^2	Compressive strength at 14 days N/mm^2	Compressive strength at 28 days N/mm^2
35%	16.2	25.4	32.5
40%	17.0	28.0	34.7
45%	14.8	26.6	31.5
50%	14.5	21.2	28.4

Table 14 Compressive strength Test on 40% replacement of CS and SCBA replacement

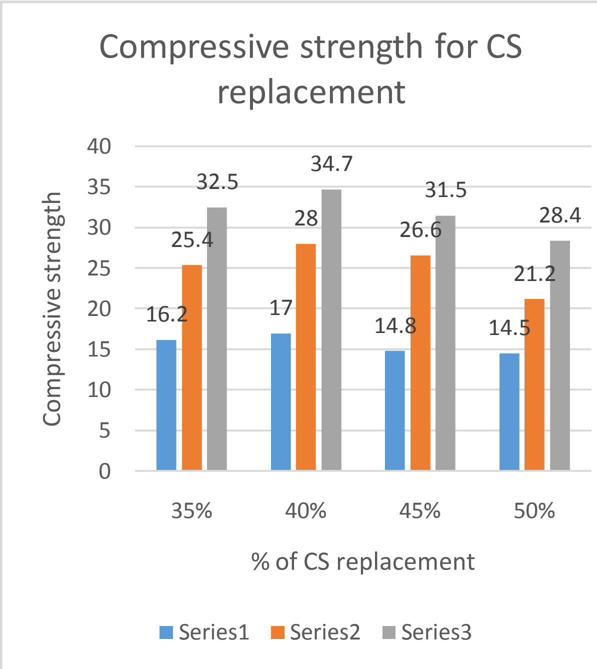
Percentage replacement of SCBA	Compressive strength at 7 days N/mm^2	Compressive strength at 28 days N/mm^2
5%	15.84	30.12
10%	12.65	25.54
15%	9.70	20.17

Figure 7 Compressive strength of Conventional Concrete



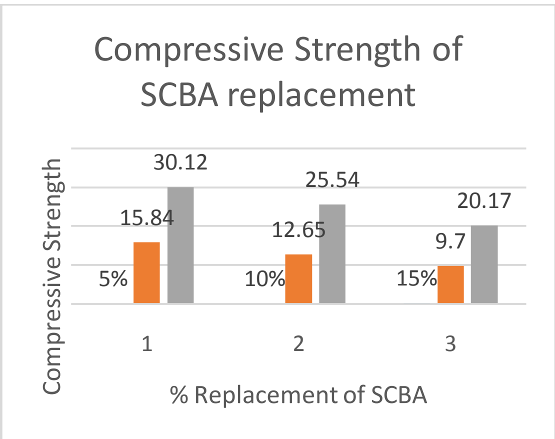
From the graph it is obtained that the nominal compressive strength of the concrete is found to be **29.35 N/mm^2**

Figure 8 Compressive strength of CS Replaced Concrete



From the graph it is obtained that the compressive strength of the CS replaced concrete is found to be high at a replacement of **40%** and hence this value is found to be the optimum value

Figure 9 Compressive strength on 40% replacement of CS and SCBA replacement



From the graph it is obtained that for the replacement of fine aggregate by **40% of CS** and the replacement of Cement by SCBA the **optimum value was found to be 5%**, since the compressive strength was high for that replacement.

2 SPLIT TENSILE STRENGTH

Table 15 Tensile Strength test on conventional concrete

Conventional Concrete	Tensile strength at 7 days N/mm^2	Tensile strength at 14 days N/mm^2	Tensile strength at 28 days N/mm^2
CS1	2.5	3.5	4.1
CS2	2.4	3.3	4.2

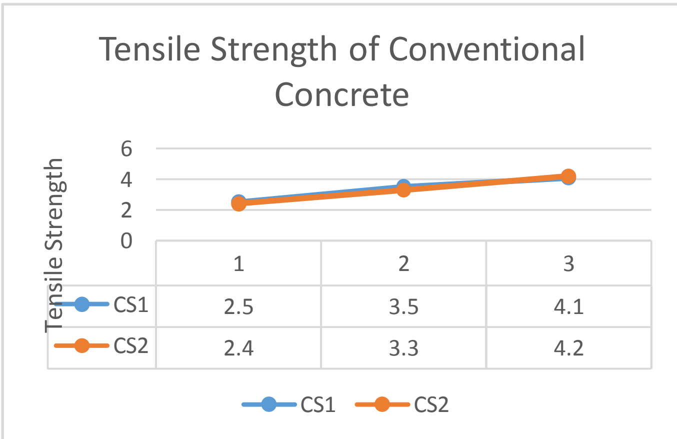
Table 16 Tensile Strength test on Copper Slag replacement

Percentage replacement of Copper Slag	Tensile strength at 7 days N/mm^2	Tensile strength at 14 days N/mm^2	Tensile strength at 28 days N/mm^2
35%	2.6	2.6	2.8
40%	2.8	3.1	3.5
45%	2.4	2.5	2.7
50%	2.1	2.2	2.4

Table 17 Tensile Strength test on SCBA replacement

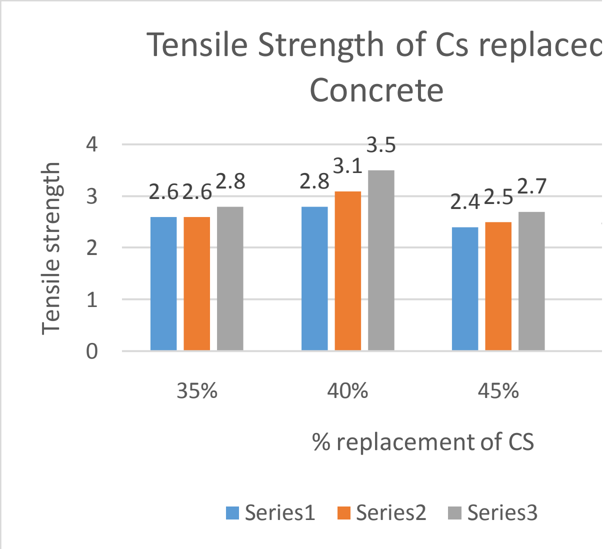
Percentage replacement of SCBA	Tensile strength at 7 days N/mm^2	Tensile strength at 28 days N/mm^2
5%	2.1	4.0
10%	1.8	3.5
15%	1.6	3.3

Figure 10 Tensile Strength of Conventional Concrete



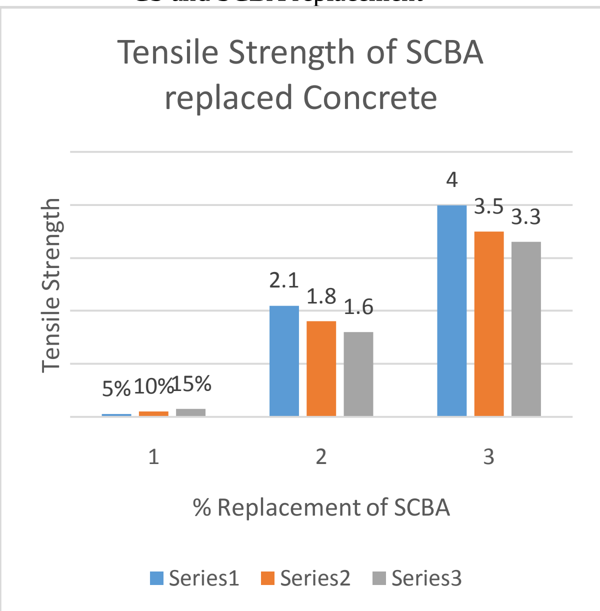
From the graph it is inferred that the tensile strength value for the conventional concrete was found to be **4.1 N/mm^2**

Figure 11 Tensile Strength of CS replaced Concrete



From the graph it is inferred that the tensile strength of the concrete was found to be high for the **CS replacement of 40%** and this value is the optimum value for the concrete

Figure 12 Tensile Strength on 40% replacement of CS and SCBA replacement



From the graph it is inferred that the **SCBA** replacement for **40% replacement** of fine aggregate by Copper slag was found to **5%** and this value is the optimum value.

VIII CONCLUSION

This project deals about the replacement of fine aggregate by copper slag and cement by Sugarcane bagasse ash. Also in the selected mix, copper slag is partially replaced from 35-50% in the difference of 5% resulting a greater a compressive strength at 40% for the coppers slag replacement. For the replacement of SCBA for cement the highest compressive strength of the replacement was found to be 5%. The optimum value was found to be 40% replacement for Copper slag replacement of Fine Aggregate and 5% of SCBA replacement of Cement. The workability of concrete increased with the increase in copper slag replacement of fine aggregate. The construction industry is the only area for safe use of waste materials, which reduces the environmental problems, space problems and cost of construction. The early age compressive strength of concrete specimens can be improved by 40% replacement of fine aggregate by copper slag and 5% replacement of Sugarcane Bagasse Ash by cement. Compared to the control mix, there was a slight increase in the concrete density of nearly 5%, with the increase of copper slag content. Further addition of copper slag and sugarcane bagasse ash resulted in lesser strength values when compared to the control mix. It should be noted that further research work is needed to explore the effect of Copper slag and SCBA replacement on concrete specimen with different cement types.

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