EXPERIMENTAL STUDY OF CONCRETE WITH COPPER SLAG FOR PARTIAL REPLACEMENT OF FINE AGGREGATE

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Abstract - *In order to avoid using natural river sand. An alternative material is proposed to the strength of the concrete by replacing of fine aggregate. Partially by waste material like copper slag which is an environmental waste. To make us of these material without sacrifice the strength and durability of the concrete structure. To strength is measured by use of non-destructive and destructive techniques. The effects of replacing fine aggregate by copper slag on the compressive strength are attempted in this work. This work includes the determination of different properties of locally available copper slag and utilization of copper slag in concrete by replacing it partially by fine aggregate keeping the other parameters constant. Compressive strength of concrete cubes on M20 grade of concrete with constant 0.50 w/c ratio. Copper slag replacement of 0%, 10%, 20%, 30%, 40%, and 50% are used. This experimental study presents the result of compressive strength test on concrete containing copper slag partially replaced by fine aggregate. The obtained results were compared with those of conventional cement concrete made with Ordinary Portland Cement.*

Key Words: Copper Slag, Fine Aggregate, M20 Grade, Compressive Strength, Environmental Waste.

1. INTRODUCTION

1.1 GENERAL

Many countries are witness a rapid growth in the construction industry which involves the use of natural resources for the development of the infrastructure. Natural resources are depleting world-wide while at the same time the generated wastes from the industry are increasing substantially. River sand, which is one of the constituents used in the production of conventional cement mortar, has become highly expensive and also scarce. The sustainable development for construction involves the use of non-conventional and innovative materials, and recycling of wastes in order to compensate the natural resources and to find alternative ways for conserving the environment.

Large amount of industrial wastes or byproducts accumulate every year in all developing countries. Therefore now a day's utilization of secondary materials has encouraged in construction field. For the production of cement and concrete very high amount of energy is needed. Around 7% of CO_2 released to atmosphere is appeared during cement production. Harmful effects of concrete by using on environmental can be reduced by producing good and durable concrete by using industrial by products.

The presence of copper, alumina, sulphate in the slag were only traces and harmful. The properties of fine aggregates at all chemical composition of slag is replacement levels are similar to the presented in table-1 and sieve analysis of specification for sand zone II as per IS:383. High strength concrete has to be designed for higher workability, higher mechanical properties and greater durability than those of conventional concrete. The definition of high strength concrete is continuous to change as advances in concrete technology make it easier to achieve increasing higher strength and greater workability using conventional construction practice. In order to achieve high strength concrete with good mechanical properties and durability, fly ash or silica fume that are considered as waste material are used as one of the main ingredients. The recent research showed that the possibility of utilizing industrial byproducts as well as other material in the production of normal concrete and high strength concrete, when used as partial or full replacement of cement mortar and aggregates or as admixtures. This research study presents the results of experimental work conducted on the performance of high strength concrete mortar made with copper slag as fine aggregate. The effects of admixtures made with copper slag has been discussed.

1.2 COPPER SLAG

Copper slag is a byproduct obtained the metal smelting and refining of copper. Copper slag used in this work was brought from Sterlite Industries Ltd (SIL), Tuticorin, and Tamilnadu, India. SIL is produced per day and a total accumulation of around 1.5 million tons. It is a byproduct obtained during the metal smelting and refining of copper. To produce every ton of copper approximately 2.2-3.0 tons copper slag is generated as a byproduct material. Utilization of copper slag in application such as Portland cement substitution and as aggregates has threefold advantages of eliminating air pollution problems.

The countermined copper slag has to be properly treated or washed to meet certain recycling criteria before it can be further used for other application. The products of one ton copper generates approximately 2-3 tons of copper slag.

Copper slag is the toxic for environment because it contains large amount of heavy metals in their oxide. Separated impurities are collected and removed and various substance are added to purified metal which melt it and enrich it, and in those processes slag is generated again as a byproducts.

This type of generated slag depends on the method of cooling of the melted mass on the type of processes metal.

The production of granulated slag sand sized grains are created. Due to its composition, this material has excellent hydraulic properties and in the presence of an appropriate will behave in a manner similar to Portland cement.

Expanded for any slag is more porous and has a smaller volume than air cooled slag. The current quantity of copper slag is estimated at approximated 2.2 million tons. A large quantity of this material on landfill and its potential as a substitute for traditional material has investigated to carry out research into the possibilities of various applications of slag construction primarily as aggregate in concrete mixtures.

Fig -1: Copper Slag

1.3 BASIC PROPERTIES OF COPPER SLAG

The slag is a black glassy and granular in nature and has a similar particle size range like sand which indicate that it could be tried as replacement for the sand in cementite's slag mixture. The specific gravity of copper slag is varying between 1.7-1.90 g/cc. which is almost similar to the bulk density. The hardness of gypsum. The pH of aqueous solution of aqueous extract as per IS 11127 is 11ppm. The slag is conforming to the above standards.

The free moisture content present in slag was found to be less than 1%. The sieve analysis for copper slag infers that the gradation properties of fine aggregates at all the replacement levels are similar to the specification for sand zone II as per IS: 383. The chemical composition of slag is presented on table-1 and sieve analysis report is shown of table-2. The presence of silica in slag is about 26% which is desirable since it is one of the constituents of the natural fine aggregate used to normal concreting operations.

The presence of copper, alumina, sulphate in the slag were only traces and harmful. The properties of fine aggregates at all chemical composition of slag is replacement levels are similar to the presented in table-1 and sieve analysis of specification for sand zone II as per IS:383.

In the composition of copper slag there is a significant considered responsible for the biggest lack of this material and its limited usage in road, building. Namely copper slag is very expansive and due to this reason the volume can change by as much as 10% slag weathering in atmosphere conditions is considered to be one of the most appropriate methods of eliminating this adverse property. The weathering period varies depending on the application method and the type of slag itself. Therefore it sometimes takes only several months of weathering in atmospheric conditions or occasional sprinkling with water. According to Belgian and Dutch regulations for the use of slag in unbound base course one year of weathering is sufficient whereas there are known data on the need for weathering for as much as 18 months before using the slag as aggregate.

Those obstruction are particularly dangerous in the case of freezing which renders large damage to pavement structures. This however unlike expansions cannot be prevented by slag weathering.

The grains of this material are pointed with rough surface and this is particularly suitable in the case of use in asphalt mixtures for reason of an increasing in adhesiveness between the pavement and wheels. The big angle of internal friction (40-45) contributes to big stability of materials and CBR value of up to 200%. Copper slag belongs to medium alkaline material with pH values 6.6-7.2.

1.4 SCOPE

The scope of the work includes the studies on the following aspects of cement mortar and cement concrete.

- Evaluation of copper slag based on cement mortar in brick masonry construction.
- The percentage of copper slag used for replacement of river sand are 0%, 10%, 20%, 30%, 40%, 50%.
- Cement sand mortar joint thickness of 10 and 15mm.
- Plaster ability of use of copper slag for partial replacement material for river sand.
- Use of copper slag as replacement material for river sand in cement concrete.

1.5 OBJECTIVES

- Copper slag has also gained popularity in the building industry for use as a fill material.
- Used copper slag in place of sand during concrete construction.

- Copper slag can also use as a building material formed into blocks.
- It is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools.

Copper slag is used as an abrasive media to remove rust, old coating and other impurities in dry abrasive blasting due to its high hardness.

2. MATERIAL, METHODOLOGY AND TESTING

2.1 MATERIALS

2.1.1 CEMENT

Copper slag is used as an abrasive media to remove rust, Cement is a well-known building material has occupied an indispensable place in construction works. Cement is an extremely ground material having adhesive ingredients. It is obtained by burning together, in a definite proportion, a mixture of ingredients. It is obtained by burning together in a definite proportion, a mixture of naturally occurring argillaceous and calcareous, cooled and ground to the required the required fineness to produce material known as cement.

In general cement is a binder a substance that sets and hardens independently and can bind other materials together. The word `cement` is used to describe masonry resembling modern concrete that was made from crushed rock with burnt lime as binder.

Ordinary Portland Cement was used for casing concrete. This cement is the most widely used one in the construction industry in India. The grade of cement is 53 with specific gravity of 3.15. The initial time and final setting time were found to be 30min and 600min respectively.

2.1.2 AGGREGATE

These are chemically inert, solid bodies held together by the cement. Aggregates come in various shapes, sizes and material ranging from fine particle of sand to large rocks. Because cement is the most expensive ingredients in making concrete, it is desirable to minimize the amount of cement used 70%-80% of the volume of concrete is aggregate keeping the cost of the concrete low. Generally flat and elongated particles are avoided or are limited to about 15% by weight of the total aggregate. Unit weight measures the volume that graded aggregate and the voids between them will occupy in concrete. The void content between particles affects the amount of cement paste required for the mix.

Selecting equal sizes of well graded aggregates reduce the void content. Absorption and surface moisture of aggregate are measured while selecting aggregate because the internal structure of aggregate is made up of solid material and voids that may affect the water cement ratio.

2.1.3 AGGREGATE

2.1.3.1 FINE AGGREGATE

Fine aggregate used for concrete should be properly graded to give minimum void ratio and be free from deleterious material like clay, slit content and chloride contamination etc. Hence grading of fine aggregate is relatively different from that in normal concrete. Grading of fine aggregate should be such that it does not cause increase in water demand for the concrete and should give maximum voids so that the fine cementations particles to fill the voids. Hence it is desirable to use the coarser variety of fine aggregate having a high fineness modulus for making workable and strong concrete. The fine aggregate having are taken in saturated surface dry condition.

2.1.3.2 COARSE AGGREGATE

Local aggregate comprising 20mm, and less than 20mm coarse aggregates in saturated surface dry condition, were used. The coarse aggregates were crushed granite type aggregates. Coarse aggregate were obtained in crushed from majority of the particles were of granite type. The quality is tested using impact test.

2.1.3.3 COPPER SLAG

The copper slag used in this study have glassy appearance and black in color. It having the specific gravity of 3.68 and the compacted unit weight as 8.75 KN/m3. The particle size of the copper slag is similar to the river sand i.e. sieve size from 4.75mm to 75 micron.

The tests which conducted on river sand is also carried on copper slag.

Table -1: Physical properties of copper slag

Physical properties of copper slag	
Colour	Black
Specific gravity	3.68
Appearance	Glassy
Compacted unit weight (KN/m3)	8.75
Absorption	5%

Table -2: Chemical properties of copper slag

Chemical properties of copper slag	
Iron (Fe_2O_3)	68.29%
Silica dioxide (SiO_2)	25.84%
Calcium oxide (CaO)	0.15%
Aluminum oxide(Al_2O_3)	0.22%
Iron (Fe_2O_3)	68.29%

2.1.4 WATER

It is the key ingredient mixed with cement, forms a paste that binds the aggregate together. The water causes the hardening of concrete through a process called hydration. Hydration is a chemical reaction in which the major compound in cement form chemical bonds with molecules because the water to cement ratio is the most critical factor in the design of perfect concrete. Excess of water reduces strength and workability of concrete.

Portable tap water available in the plant conforming to the requirements of IS456-2000 was used for casting concrete & curing the specimens.

2.2 METHODOLOGY FLOW CHART

Chart -1: Flow chart

2.3 TESTS

2.3.1 TESTS ON FINE AGGREGATE

In this project, the river sand, which was available in saturated surface dry condition was used as fine aggregate and the following tests were carried out on sand as per IS:2386-1968(iii):

- Sieve analysis
- Density
- Specific gravity
- Water absorption

2.3.2 TESTS ON COARSE AGGREGATE

The coarse aggregate are tested for the following

- Impact value
- Sieve analysis
- Density
- Specific gravity
- Water absorption

2.3.3 TESTS ON COPPER SLAG

The copper slag is tested separately for the following

- Sieve analysis
- Density
- Specific gravity
- Water absorption

SIEVE ANALYSIS TEST

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregate. This is done by sieving the aggregates as per IS: 2386 (part I) 1963. In this we use different sieves as standardized by the IS code and then pass aggregate through them and collect different sized particles left over different sieves.

DENSITY

The density of both fresh and hardened concrete is of interest to the parties involved for numerous reasons including its effect on durability, strength and resistance to permeability. Hardened concrete density is determined either by simple dimensional check followed by weighing and calculation or by weight in air water buoyancy method.

SPECIFIC GRAVITY TEST

Purpose

This test is performed to determined specific gravity of material by using a pycnometer. Specific gravity is the ratio of the mass of unit volume of material at stated temperature to the mass of same volume of gas free distilled water at the stated temperature.

Standard reference

IS: 2720 (part 3) 1980, first revision – standard test for specific gravity of material is used as reference for testing.

Significance

The specific gravity of a material is used in the phase relationship of air water and solid in the given volume of material.

Specific gravity $= \frac{W_0}{[W_0+(Wa-Wb)]}$

W_0 = weight of sample material, g=Wps-Wp

WA = weight of pycnometer filled with water

WB = weight of pycnometer filled with water and material.

WATER ABSORPTION

This process is particularly important on concrete for durability. Absorption capacity is a measure of porosity of a material. It is also used as a correlation factor in determination of free moisture by oven dry method. The absorption capacity is determined by finding the weight of surface dry sample after it has been soaked for 24 hours and again finding the weight after sample has been dried in an oven. The difference in weight expressed as a percentage of dry sample weight.

Water absorption = (increased weight in kg/weight of specimen in kg) ×100

3. TEST RESULTS

3.1 SPECIFIC GRAVITY TEST

3.1.1 COPPER SLAG

Instrument used = Pycnometer

Material used = Copper slag

Observations:

1. Weight of pycnometer (W1) = 630 g
2. Weight of pycnometer + copper slag (W2) = 1330 g
3. Weight of pycnometer + full water + copper slag (W3) = 2070 g
4. Weight of pycnometer + full water (W4) = 1560 g

Specific gravity $= \frac{W2-W1}{[(W2-W1)-(W3-W4)]}$

$= \frac{1330-630}{[(1330-630)-(2070-1560)]}$

G = 3.68

3.1.2 FINE AGGREGATE

Instrument used = Pycnometer

Material used = Fine aggregate

Observations:

1. Weight of pycnometer (W1) = 630 g
2. Weight of pycnometer + Fine aggregate (W2) = 950 g
3. Weight of pycnometer + full water + Fine aggregate (W3) = 1560 g
4. Weight of pycnometer + full water (W4) = 1360 g

Specific gravity $= \frac{W2-W1}{[(W2-W1)-(W3-W4)]}$

$= \frac{950-630}{[(950-630)-(1560-1360)]}$

G = 2.68

3.1.3 COARSE AGGREGATE

Instrument used = Pycnometer

Material used = Coarse aggregate

Observations:

1. Weight of pycnometer (W1) = 630 g
2. Weight of pycnometer + Coarse aggregate (W2) = 1010 g
3. Weight of pycnometer + fullwater+Coarse aggregate (W3) = 1640 g
4. Weight of pycnometer + full water (W4) = 1395 g

Specific gravity $= \frac{W2-W1}{[(W2-W1)-(W3-W4)]}$

$= \frac{1010-630}{[(1010-630)-(1640-1395)]}$

G = 2.80

3.1.4 CEMENT

Instrument used = Pycnometer

Material used = Cement

Observations:

1. Weight of pycnometer (W1) = 630 g
2. Weight of pycnometer + Cement (W2) = 1080 g
3. Weight of pycnometer + kerosene + Cement (W3) = 1600 g
4. Weight of pycnometer + kerosene (W4) = 1263 g
5. Specific gravity of kerosene = 0.79

$$\text{Specific gravity} = \left\{\frac{W2-W1}{[(W2-W1)-(W3-W4)]}\right\} \times 0.79$$

$$= \left\{\frac{1330-630}{[(1330-630)-(2070-1560)]}\right\} \times 0.79$$

G = 3.15

3.2 SIEVE ANALYSIS

3.2.1 COPPER SLAG

Instrument used = Sieve

Material used = Copper slag

Weight of material = 500 g

Table -3: Sieve analysis on Copper slag

IS Sieve Size	Weight retained (g)	% of weight retained	Cumulative % retained	% of passing
4.75 mm	32	6.4	6.4	93.6
2.36 mm	58	11.6	18	82
1.18 mm	126	25.2	43.2	56.8
600 μ	98	19.6	62.8	37.2
300 μ	94	18.8	81.6	18.4
150 μ	78	15.4	97	3
Pan	16	3	100	0

Fineness modulus = 504/100

= 5.04

3.2.2 FINE AGGREGATE

Instrument used = Sieve

Material used = Fine aggregate

Weight of material = 1000 g

Table -4: Sieve analysis on Fine aggregate

IS Sieve Size	Weight retained (g)	% of weight retained	Cumulative % retained	% of passing
4.75 mm	0.01	10	1	99
2.36 mm	0.06	70	7	93
1.18 mm	0.36	430	43	57
600 μ	0.27	700	70	30
300 μ	0.19	890	89	11
150 μ	0.09	980	98	2
Pan	0.02	1000	100	0

Fineness modulus = 408/100

= 4.08

3.2.3 COARSE AGGREGATE

Instrument used = Sieve

Material used = coarse aggregate

Weight of material = 2000 g

Table -5: Sieve analysis on Coarse aggregate

IS Sieve Size	Weight retained (g)	% of weight retained	Cumulative % retained	% of passing
125	**0**	**100**	**0**	**100**
100	0	100	0	100
75	0	100	0	100
50	0	100	0	100
40	0	100	0	100
25	730	63.5	36.5	63.5
12.5	2000	0	100	0
10	2000	0	100	0

Fineness modulus = 236.5 / 100

= 2.365

3.3 WATER ABSORPTION TEST

3.3.1 FINE AGGREGATE

Table -6: water absorption of fine aggregates

Sample no.	Weight of oven dried specimen (W1) Kg	Weight of saturated specimen (W2) Kg	Weight of absorbed water W3=W2-W1 Kg	% of water absorption =(W3/W1)×100
1	0.995	1.01	0.015	1.5

3.3.2 COARSE AGGREGATE

Table -7: water absorption of Coarse aggregates

Sample no.	Weight of oven dried specimen (W1)Kg	Weight of saturated specimen (W2)Kg	Weight of absorbed water W3=W2-(W1)Kg	% of water absorption =(W3/W1)×100
1	1.166	1.172	0.006	0.51

3.3.3 COPPER SLAG

Table -8: water absorption of Copper Slag

Sample no.	Weight of oven dried specimen (W1) Kg	Weight of saturated specimen (W2) Kg	Weight of absorbed water W3=W2-W1 Kg	% of water absorption =(W3/W1) ×100
1	0.960	1.380	0.42	0.4

3.4 COMPRESSIVE STRENGHT TEST ON CONCRETE CUBE (M20)

FORMULA USED

Compressive strength = (load/area) N/mm^2

3.4.1 Compressive strength for 7 days

Table -9: Compressive strength after 7 days

TRIAL	CONCRETE TRIAL	LOAD IN (KN)	COMPRESSION STRENGTH (N / mm^2)	AVERAGE COMPRESSION STRENGTH (N / mm^2)
CC	Conventional Concrete	467 470 467	20.77 20.89 20.74	20.80
CS1	10% Copper Slag	470 471 471	20.88 20.94 20.94	20.92
CS2	20% Copper Slag	473 482 485	21.00 21.40 21.54	21.30
CS3	30% Copper Slag	513 518 513	22.80 23.00 22.80	22.90
CS4	40% Copper Slag	482 485 484	21.40 21.54 21.50	22.48
CS5	50% Copper Slag	438 440 442	19.48 19.54 19.56	19.56

Therefore CS3 have a better strength when compared with others after 7 days

3.4.2 Compressive strength for 28 days

Table -10: Compressive strength after 28 days

TRIAL	CONCRETE TRIAL	LOAD IN (KN)	COMPRESSION STRENGTH (N / mm^2)	AVERAGE COMPRESSION STRENGTH (N / mm^2)
CC	Conventional Concrete	649 642 646	28.84 28.54 28.73	28.70
CS1	10% Copper Slag	755 760 763	33.54 33.78 33.89	33.73
CS2	20% Copper Slag	807 808 830	35.87 35.90 36.87	36.21
CS3	30% Copper Slag	853 853 858	37.89 37.90 38.14	38.54
CS4	40% Copper Slag	895 898 913	39.78 39.89 40.56	40.28
CS5	50% Copper Slag	821 830 829	36.50 36.89 36.83	36.74

Therefore CS3 have a better strength when compared with others after 28 days

3.4.3 RESULTS FOR COMPRESSION TEST

Table -11: Compression test results After 7 & 28 days

TRIAL	Mix	7 Days	28Days
CC	Conventional Concrete	20.80	28.70
CS1	Copper Slag 10%	20.92	33.73
CS2	Copper Slag 20%	21.30	36.21
CS3	Copper Slag 30%	22.90	38.54
CS4	Copper Slag 40%	21.48	40.28
CS5	Copper Slag 50%	19.56	36.74

3.4.4 COMPRESSION STRENGTH AFTER 7 DAYS 7& 28 DAYS

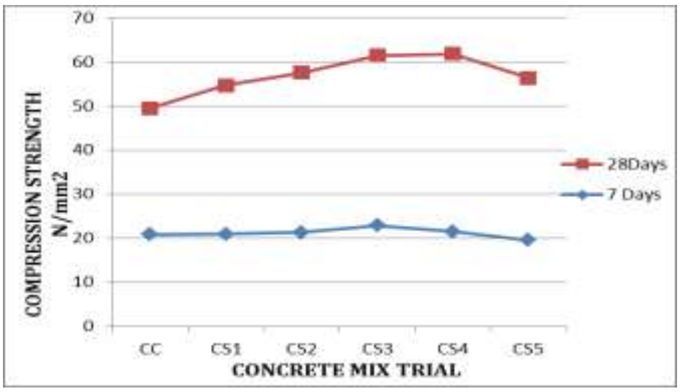

Chart-2: Compression strength results

3.5 Cost Analysis

Cost analysis is the very important factor to be considered, while analyzing the project. The cost analysis for various mixes per m^3 is shown in Table no 4.6

According to that, the cost for reference concrete mix specimen took Rs 5817.4. per m^3. Replacing 10%, 20%, 30%, 40%, 50% of copper slag in sand, it cost should be low when compared with "R".

Table -12: Cost of Material

Materials	Quantity	Rate in "₹"
Cement	1 bag (50 kg)	420
Copper slag	1bag (50 kg)	150
Fine aggregate	per cft	120
Coarse aggregate	per cft	110

where,

1 unit = 100 cft

1 unit = 2830 kg

Table -13: Rate of material per "kg"

Materials	Rate in "₹"
Cement	8.5
Copper slag	3.0
Fine aggregate	1.5
Coarse aggregate	1.4

Table -14: Total Cost of Materials for M_{20} design mix concrete (1:1.53:3.45) per m^3

s.no	MIX	Consumption of Design Proportion For M20 concrete (1:1.53:3.45)				TOTAL COST per "m³"	% COST SAVING
		C	F.A.	C.S	C.A.		
1	CC	372	570	-	1286	5817.4	-
2	CS1	372	513	57	1286	5902.9	1.46
3	CS2	372	456	114	1286	5988.4	2.93
4	CS3	372	399	171	1286	6073.9	4.40
5	CS4	372	342	228	1286	6159.4	5.78
6	CS5	372	285	285	1286	6244.9	7.34

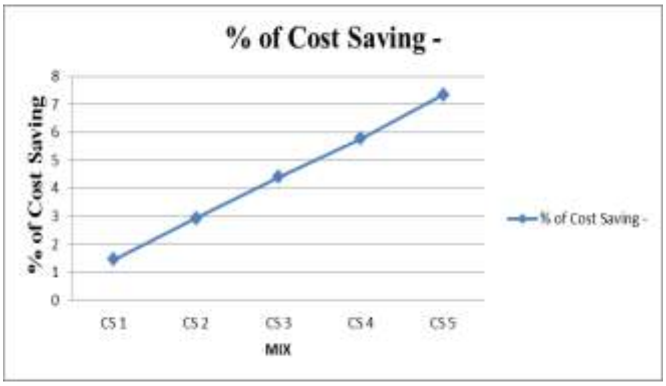

Chart-3: Percentage of improvement of cost Analysis

4. CONCLUSION

Based on the test results obtained from the experimental program of this work the following major calculations are arrived from workability, compressive strength and cost analysis.

4.1 WORKABILITY TEST

Slump Cone Test

From the workability test results, slump value slightly decreases for concrete mixes with Copper slag when compared with reference concrete mix (R).

After 7 days curing

From the experimental test results, the compressive strength of concrete mix of cube having 30% of copper slag (CS3) has the higher strength of 22.90Mpa.

After 28 days curing

From the experimental test results, the compressive strength of concrete mix of cube having 40% of copper slag (CS4) has the higher strength of 40Mpa.

By analyzing its cost and strength parameters concrete mix having 40% replacement of cement by copper slag (CS4) is comparatively more economical.

4.2 COST ANALYSIS

By analyzing its cost and strength parameters concrete mix having 40% replacement of Sand by Copper slag (CS4) is comparatively more economical.

From workability, strength test and cost analysis, it is found those concrete mix with 40% replacement of Sand by Copper slag give better result and hence used to construction purpose.

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