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An Experimental Study on Strength and Durability of Concrete by Partial Replacement of Coarse Aggregate with Steel Waste and Fine Aggregate with Copper Waste

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ABSTRACT
Global warming and environmental destruction have become the major issue in recent years. Emission of greenhouse gases from industries has impact on climate change. Preventing the depletion of natural resources and enhancing the usage of waste materials has become a challenge to the scientist and engineers. A number of studies have been conducted concerning the protection of natural resources, prevention of environmental pollution and contribution to the economy by using this waste material. The major byproducts of industry are slag. To solve the problem in effective manner slag is use in concrete by replacing natural coarse aggregate. In this study, the replacement was done with coarse aggregate by steel waste and copper for a M20 grade of concrete is used for a water cement ratio of 0.40.Tests on compressive strength at 7 days and14 days are conducted on specimens. The optimum strength is obtained on 30% replacement of coarse aggregate and fine aggregate by steel waste and copper waste. All mechanical properties were enhanced with the use of copper slag. Copper slag improved the resistance against chloride penetration. 40% copper slag partial replacement enhanced the properties of self-compacting concrete, and up to 60% of fine aggregate can be substituted with industrial copper waste. By this investigation,copper slag can be used as a sustainable building material.
Key words : Steel waste, Copper waste

1. INTRODUCTION
Steel slag is a by-product obtained from melting steel scrap from the impurities and fluxing agents, which form the liquid slag floating over the liquid steel in arc or induction furnaces or other melting units. Waste management is one of the most common and challenging problem in the world. The steel making industry has generated substantial solid waste. Steel slag is a residue obtained from steel making operaion. Now-a-days using waste as an alternative for concrete mixtures. This is very helpful to reduce waste disposal, its area and environment pollution. Steel slag, Quarry dust, Copper slag are some of the industrial wastes. Copper slag is an industrial waste obtained from the copper manufacturing industry. For one tone of copper production, almost 2 to 3 tons of copper waste will be generate. Copper slag may be one of the feature alternative building materials because of its properties. Due to glassy morphology, water demand for concrete for hydration is drastically step down. Copper waste usage in concrete enhanced the fresh properties by the very low water absorbing behavior. Generally, copper waste will be ne in nature with particle nature less than 4.5mm, similar to the ne aggregate. However, industrial copper waste particle sizes are finer than the usual river sand. Previous studies stated that copper slag in concrete would improve the life of the concrete and shows promising results against corrosion and water absorption. Copper slag is a waste material which is a partial or full substitution of either cement or aggregate. It is an industrial by-product formed during the process of smelting and refining of copper. Approximately 2.2-3.0 In

India, SIL, Tuticorin, Tamil Nadu is producing copper slag in highest percentage. Utilization of the by- products (copper slag) material in the substitution process also have a main advantage of eliminating the cost of dumping and minimizing the air as well as land pollution.

2. LITERATURE REVIEW

Fayaz Ahmed.S(2018), The compressive strength of the new concrete increased with the increase in copper slag content up to a replacement level of 40%, maximum compressive strength of concrete increased by 58% at 40% replacement of fine aggregate by copper slag. The tensile strength of the new concrete has increased up to a replacement percentage of 40%, maximum tensile strength of the new concrete increased by 33% at 40% replacement of fine aggregate by copper slag. Maximum flexural strength of the new concrete increased by 25% at 40% replacement of fine aggregate by copper slag.R R Chavan & D B Kulkarni (2013) conducted experimental investigations to study the effect of using copper slag as a replacement of fine aggregate on the strength properties and concluded that Maximum Compressive strength of concrete increased by 55% at 40% replacement of fine aggregate by copper slag and flexural strength increased by 14 % for 40% replacement. Many researchers have investigated worldwide on the possible use of copper slag as a concrete aggregate. Some of the important and published works are reviewed and presented briefly below. Al-Jabri et al (2009, 2011) investigated the performance of high strength concrete made with copper slag as a replacement for fine aggregate at constant workability and studied the effect of super plasticizer addition on the properties of High Strength Concrete made with copper slag. They observed that the water demand reduced by about 22% for 100% copper slag replacement. The strength and durability of High Strength Concrete improved with the increase in the content of copper slag of upto 50%. However, further additions of copper slag caused reduction in the strength due to increase in the free water content in the mix. Also, the strength and durability characteristics of High Strength Concrete were adversely affected by the absence of the super plasticizer from the concrete paste despite the improvement in the concrete strength with the increase of copper content. The test results also show that there is a slight increase in the density of nearly 5% with the increase of copper slag content, whereas the workability increased rapidly with increase in copper slag percentage.Suresh Reddy et al. (2013) studied the concrete made of copper slag replacings and up to 50% are used to study the strength parameters, compressive strength, split tensile strength and flexural strength of both M30 and M40 grade of concrete mixes. Sand was replaced with copper slag in proportions of 0%, 10%, 20%, 30%, 40% and 50%. From the results, it was concluded that the compressive strength, split tensile strength and flexural strength of concrete mix increased marginally up to 40% replacement of sand by copper slag at the age of both 28 and 56 days.K.Thangaselvi(2015) ,The replacement of coarse aggregate with steel slag has increased the compressive strength, split tensile strength and flexural strength of concrete. The optimum percentage of steel slag was found to be 60%. The increase in percentage of steel slag in concrete shows higher resistance to acid and sulphate attack. When this optimized value will be used, it will give good strength more durable concrete when compared to conventional concrete and saves material cost upto 10%.Abdullah Anwar (2018) In this paper detailed study on Strength properties of concrete by replacement of fine aggregate with copper slag and cement with silica fume. M40 grade of concrete is used, the fine aggregate was replaced with Copper Slag (40%) and cement was replaced with Silica Fume from 5% to 15% at an interval of 5%. This research study on the mechanical property of concrete at 28 days. The optimum content of silica fume find out (up to 40%) and silica fume (up to 10%). Compressive Strength was increased significantly when compared to the Nominal mix.Abhishek Maharishi et(2016).al prepared concrete (copper slag cement) by replacing fine aggregate fully as well as partially with copper slag. The different test was performed on the concrete like split tensile strength, compressive strength, void, acid attack, durability test. GGBS also used by taking 30% fix replacement in every mix. The 100 mm cubes was prepared to perform the compressive strength & durability test. Concrete was tested after 3, 7 & 28 days [11]. Results showed that durability and Compressive Strength were increased when the fine aggregate

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replaced with copper slag up to 40% but strength fall down after 40% replacement. AnkitNainwalet.(2017) worked on the concrete by replacing fine aggregate partially. Fine aggregate replaced with the Copper Slag at 0%, 20%, 40%, 60%. The work was investigated for split tensile test, compressive strength as well as durability of concrete. The test result shown that compressive strength and durability were nearer to the conventional concrete at 40% replacement with Copper Slag. The Water absorption decreased with increment of copper slag up to 60%. It was observed that mechanical properties of concrete vary for different percentage of copper slag at different places. BinayaPatnaiket.(2018) prepared M20 grade concrete for investigation by partial replacement of fine aggregate by copper slag with 0,10,20,30,40,50 percent .The concrete tested by 7,28, 90 days. Compressive strength test were performed on the cubes and it has been found that compressive strength decreased with increment in copper slag after 40%.It also been observed that cost of concrete by using copper slag was less compared to conventional concrete.

3. Materials & Methods

A preliminary study on compressive strength, tensile strength and flexural using different proportions of steel and copper concrete resulted in a ratio of steel and copper concrete 30% by volume of concrete. In the present study, experimental concrete cubes of size 150mm x 150mm, in thickness of 150mm and cylinder of diameter 150mm and height of 300mm, both with PCC (plain concrete) and replaced aggregate concrete with experimental were cast and tested for compression, tensile for 7 ,14 and 28 days of curing. A concrete beam of size 150mm x 150mm x 500 mm were casted and tested for flexural strength after 7 ,14 and 28 days. Partial replacement of coarse aggregate and fine aggregate with steel and copper concrete can, in general, be produced using conventional concrete practice, though there are obviously some important differences. The basic problem is to introduce a sufficient volume of uniformly dispersed to achieve the desired improvements in mechanical behavior, while retaining sufficient workability in the fresh mix to permit proper mixing, placing and finishing. The performance of the hardened concrete is enhanced more by steel and copper with a proper shape, since this improves the good matrix bond. On the other hand, a proper shape of aggregate adverse affects the workability of the fresh mix. In general, the problems of both workability and uniform distribution increase with increasing crushed aggregate shape. Partial replacement of coarse aggregate and fine aggregate with steel and copper concrete can be placed adequately using normal concrete equipment. It appears to be very stiff because the steel and copper tend to inhibit flow; however, when vibrated, the material will flow readily into the forms. It should be noted that water should be added to steel and copper concrete mixes to improve the workability only with great care, since above a w/c ratio of about 0.5, additional water may increase the slump of the steel and cooper concrete without increasing its workability and place ability under vibration.

Objectives

The objective of this study is to find out the behavior of partial replacement of coarse aggregate and fine aggregate concrete with steel and copper. However, it is expected that the use of steel and copper in concrete improve the strength properties of concrete.

- Effect of steel and copper concrete on workability.
- Effect on Compressive strength of concrete.
- Effect on Tensile strength of concrete.

Scope

Following parameters influences behavior of the steel and copper concrete, so these parameters are kept constant for the experimental work. Thus, the scope of the project can be summarized as:

- To obtain Mix proportions of Control concrete by IS method .To perform the specific gravity test, sieve analysis and slump test under Indian Standard methods.
- To conduct compressive strength, split tensile test using with and without steel and copper as per

Indian Standard methods.

4. EXPERIMENTAL INVESTIGATION

Specific Gravity Test

In concrete technology, specific gravity of aggregates is made use of in design calculations of concrete mixes. The specific gravity of each constituent known, its weight canbe converted in to solid volume and hence a theoretical yield of concrete per unit volume can be calculated. Specific gravity of aggregate is also required in calculating the compaction factor in connection with the workability measurements, similarly the specific gravity of aggregate is required to be considered when we deal with light weight and heavy weight concrete. Empty weight of pycnometer is to be taken (W1) Gms. About 1/3 portion of the pycnometer is filled with an aggregate and it is weighed (W2) gms. Now the same pycnometer is to be filled with water and it is weighed (W3) Gms. The pycnometer is to be cleaned and filled completely with only water and it is weight is to be taken(W4).

Table no. 4.1 Specific Gravity

S.No	Material	Specific gravity
1	Fine aggregate	2.478
2	Coarse aggregate	2.879

IS Sieve is calculated which shows the particle size distribution in the sand sample
Sieve Analysis Test of CA is done by a sample of aggregate shall be collected as given earlier. Sieves shall be cleaned and arranged in sequence in descending order. Pan shall at the lowermost end and Lid on top. Take around 5 kg of sample and dry it in an oven at a temp of 100-1100 The dried sample shall be then weighed (5 kg preferably) and sieved successively on sieves starting with 40mm and then through 4.75mm (For 20 mm down an aggregate size) and through 2.36 mm (For 12.5/10 mm down an aggregate size). Each sieve shall be shaken at least for two minutes on a clean tray until no more trace passes. The motion shall be varied like back and forth, left to right, circular clockwise and anti-clockwise and with frequent jarring. Material shall not be forced through the mesh. But for coarser than 20mm particles, placing is permitted (passing particles through sieve opening manually). Sieves shall be brushed from underneath of mesh and pass on to the next. On completion of sieving, material retained on each sieve is to weigh Separately. Check for permissible limits for passing.

Table no.4.2 Sieve analysis of Coarse Aggregate

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
4.75mm	750	100	0

Table no:4.3 Sieve analysis of fine aggregate

Sieve Size	Weight Retained (grams)	Cumulative percentage retained	Cumulative percentage passed
40mm	0	0	100
20mm	100	2.6	25.8
16mm	200	23.33	51.2
12.5mm	300	48.33	80.0
10mm	800	75.00	90
4.75mm	850	100	0

Sand zone Zone- III

Fig no 4.2 Sieve analysis

Slump test
The concrete slump test Slump Test (ASTM C 143M-00) is an empirical test thatmeasures the workability of fresh concrete. More specifically, it measures the consistencyof the concrete in that specific batch. This test is performed to check the consistency of freshly made concrete.
Consistency is a term very closely related to workability. It is a term which describes the state of fresh concrete. It refers to the ease with which the concrete flows. It is used to indicate the degree of wetness. Workability of concrete is mainly affected by consistency i.e. wetter mixes will be more workable than drier mixes, but concrete of the same consistency may vary in workability. It is also used to determine consistency between individual batches.
Concrete is prepared as per mix design. The freshly prepared concrete is filled in a clean slump cone in four successive layers. 25 tamping is given for each layer properly before adding another

layer. Excessive concrete is strike of with trowel from the top of the mouldafter the final layer has been tamped .The cone is removed immediately by raising it slowly and carefully in the vertical direction. The settlement or subsidence (slump) (i.e. difference between the height of the slump mould and the highest point of the subsidized concrete cone.) in cone measured as soon as it comes to stop.

Table no:4.4 Slump test

Specimen	**Slump Result**
Conventional	62 mm
5% copper,15%Steel	73 mm
5% copper,25%Steel	75 mm
5% copper,35%Steel	78 mm
5% copper,45%Steel	79 mm

The slump value 50-100mm the workability is medium

Fig no:4.3 Slump test

Concrete mix design

Calculation of material for cube (150mmx150mmx150mm)
Concrete Dry volume =1.54
Volume of cube = 150mmx150mmx150mm

=0.15mx0.15mx0.15m

=0.003375m3

Wet volume = volume of cube x dry volume

=0.003375x1.54

= 0.005197m3
M20 grade concrete ratio = 1:1.5:3 mix ratio

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Cement = $\frac{1x0.005197}{5.5}$

In kg = 0.0009449x1440 kg

= 1.36kg

Sand =0.0009449x1.5m3

In cubic feet =0.00147m3x1600

=2.2672
30% in copper = 0.68016kg70% in sand = 1.58704kg
Aggregate = 0.0009449x3m3

= 0.002834m3x1800

In cubic feet = 5.1012 70% aggregate =3.57084kg
30% Steel =1.53036 kg

Mix proportion
(M20 grade)(1:1.5:3)

(150mmx150mmx150mm)cubeCement 1.3kg
Sand 1.5kg Aggregate 3.5 kg
Copper 0.68 kgSteel 1.530kg

Mixing, curing, Compaction of Concrete

The cube mould plates first be removed and then should be cleaned and itshould ensuring that all the bolts are fully tight .cube side faces must face parallel post application a thin layer of oil to the face of mould .
Once cubes have cast ,the cube moulds should be filled with concrete sample in 3layer ,.make sure ,that each layer to compacted using vibration or through the hard ,also each layer containing the concrete should be compacted .
Now curing ,the casted cubes should be placed under the shed shouldn‟t have any sort of vibration

Fig no:4.4 Mixing, Curing, Compaction of concrete

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Compressive strength
For cube testing two types of specimens either cubes of 15cm X 15cm X 15cm or 10cm X 10cm x 10cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15cm x 15cm x 15cm are commonly used. This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of this specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on the whole area of specimen. These specimens are tested by a compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at therate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete. Concrete cube of size 150mm x 150mm x 150mm after 7 days of curing is taken out of water and allowed to dry for 1 hour and then it is placed in the testing machine by aligning centrally on the base plate of the machine. Now the load is applied and the result is being recorded for the first crack and the maximum load. The compressive strength is the main criterion for the purpose of structural design. The strength development in aggregate concrete studied at 7, 14 & 28 days. The variation of compressive strength with different percentage coarse and fine aggregate concrete over normal concrete. Result of all concrete specimens exhibited increase in compressive strength with increase of curingage.

Fig no :4.5 Compressive strength test

Table no:4.5 Mix ratio

	Percentage of steel	**Percentage of copper**
Mix 1	0%	0%
Mix 2	25	5%
Mix 3	45	5%

Table no: 4.6 Compressive strength test for mix 1

Size of the cube 150mmx150mmx150mm	**Date ofthe casting**	**Date oftest**	**Date oftest**	**Date of test**	**Compressive strength(N/mm2)**
		7days	14 days	28days	
Trial 1	20.03.23	26.03.23			13.5

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Trial 2	20.03.23	26.03.23			13.6
Trial3	20.03.23	26.03.23			13.8
Trial 1	20.03.23		02.04.23		15.2
Trial 2	20.03.23		02.04.23		15.6
Trial3	20.03.23		02.04.23		15.8
Trial 1	20.03.23			16.04.23	20.4
Trial 2	20.03.23			16.04.23	20.5
Trial3	20.03.23			16.04.23	20.6

Table no: 4.7 Compressive strength test for mix 2

Size of the cube 150mmx150mmx150mm	**Date ofthe casting**	**Date oftest**	**Date oftest**	**Date of test**	**Compressive strength(N/mm2)**
		7days	14 days	28days	
Trail 1	20.03.23	26.03.23			9.7
Trail2	20.03.23	26.03.23			9.8
Trail3	20.03.23	26.03.23			9.9
Trail 1	20.03.23		02.04.23		14.6
Trail2	20.03.23		02.04.23		14.7

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Trail3	20.03.23		02.04.23		14.9
Trail 1	20.03.23			16.04.23	19.5
Trail2	20.03.23			16.04.23	19.7
Trail3	20.03.23			16.04.23	19.8

Table no: 4.8 Compressive strength test for mix 3

Size of the cube 150mmx150mmx150mm	**Date ofthe casting**	**Date oftest**	**Date oftest**	**Date of test**	**Compressive strength(N/mm2)**
		7days	14 days	28days	
Trail 1	20.03.23	26.03.23			9.7
Trail2	20.03.23	26.03.23			9.8
Trail3	20.03.23	26.03.23			9.9
Trail 1	20.03.23		02.04.23		13.7
Trail2	20.03.23		02.04.23		13.8
Trail3	20.03.23		02.04.23		13.9
Trail 1	20.03.23			16.04.23	18.3
Trail2	20.03.23			16.04.23	18.4
Trail3	20.03.23			16.04.23	18.5

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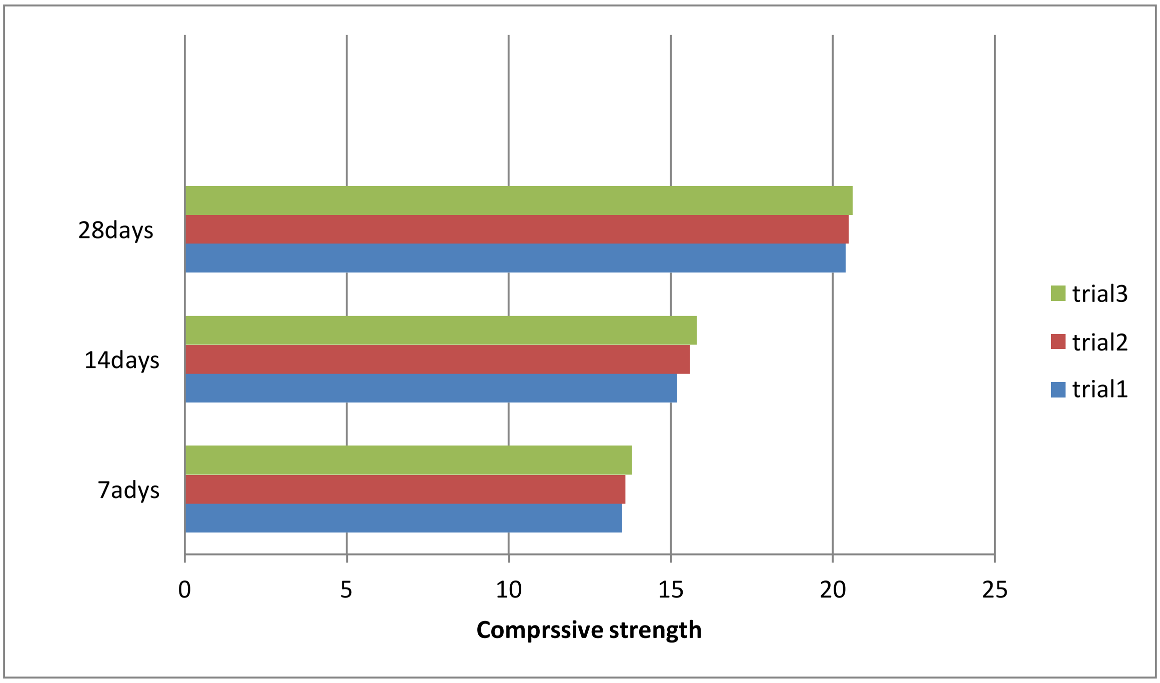

Fig no :4.6 Compressive strength for mix 1

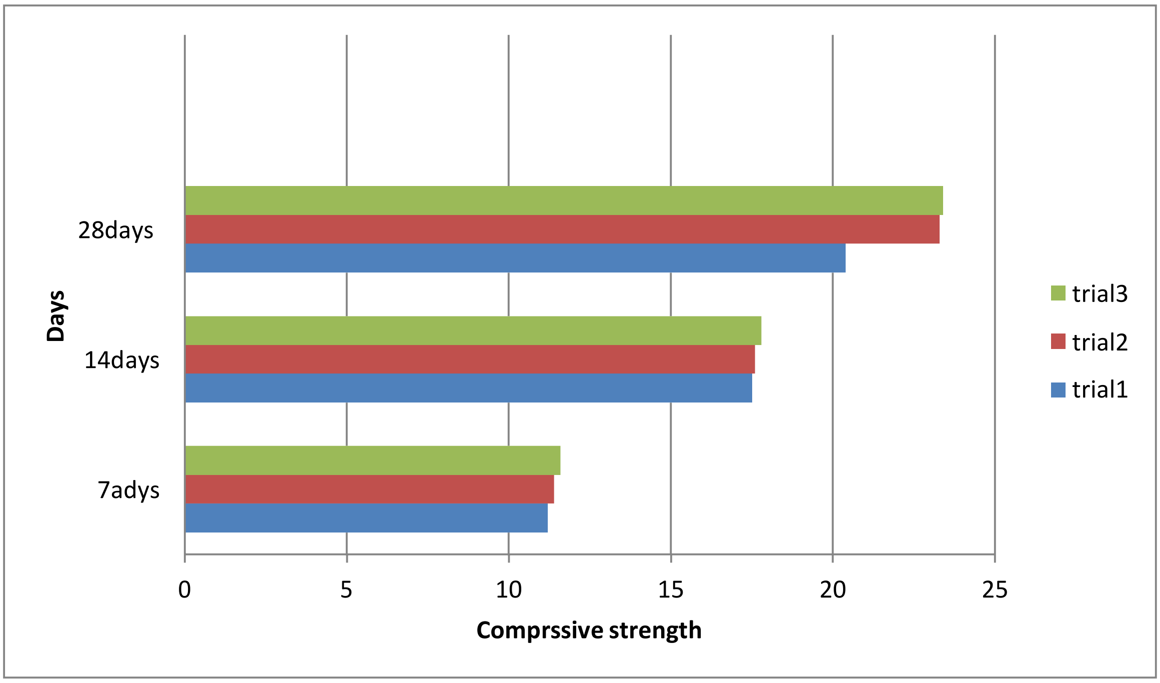

Fig no :4.7 Compressive strength for mix 2

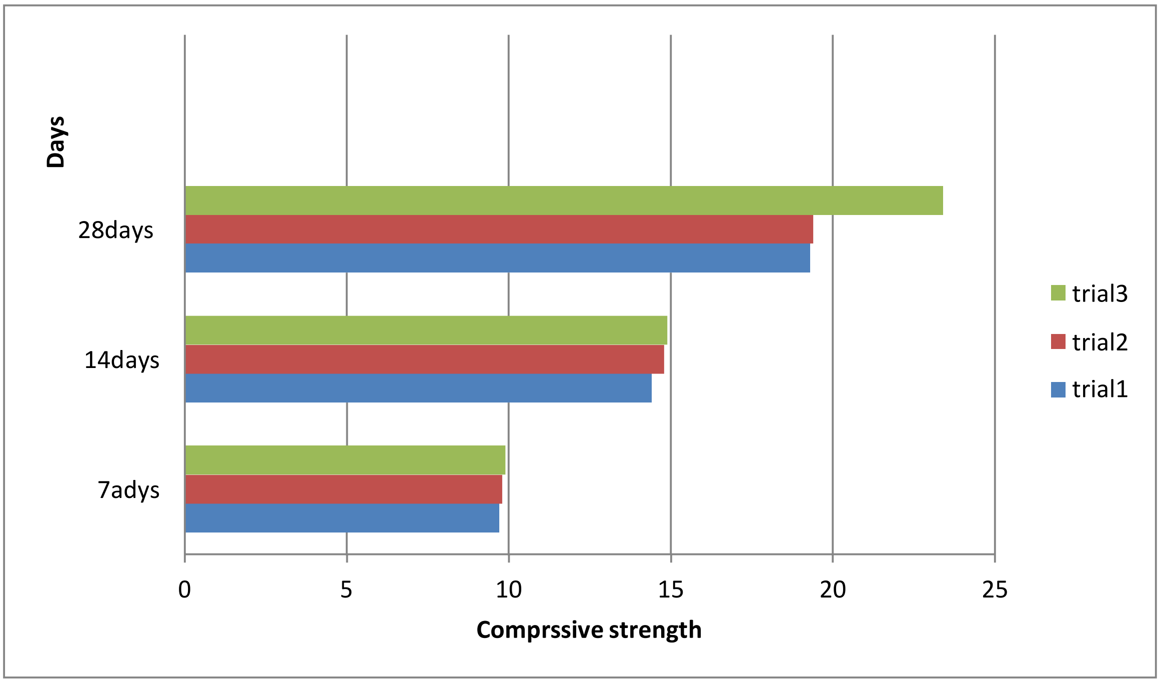

Fig no:4.8 Compressive strength for mix

Split tensile strength

This is Splitting tensile strength test is carried out at the age of 7 days for the concrete cylinder specimen of size 150mm diameter and 300mm length using universal testing machine. The load is applied gradually till the specimen split and the readings are noted. The splitting tensile strength has been estimated using the relationship

f = 2P/πdl

Where, f = Splitting tensile strength of concrete in MPa.

P = Load at failure in Newtond = Diameter of cylinder = 150mm

l = Length ofcylinder = 300mm

An indirect test to determine the tensile strength of cylindricalspecimens.

Fig no :4.9Split tensile test

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Table no:4.9 Spilt tensile test for mix 1

Size of the cube **150mmx300mm**	**Date of the casting**	**Date oftest**	**Date oftest**	**Date oftest**	**Split tensile strength(N/mm2)**
		7days	14 days	28days	
Trail 1	23.03.23	30.03.23			2.2
Trail2	23.03.23	30.03.23			2.4
Trail3	23.03.23	30.03.23			2.5
Trail 1	23.03.23		06.04.23		3.3
Trail2	23.03.23		06.04.23		3.5
Trail3	23.03.23		06.04.23		3.6
Trail 1	23.03.23			19.04.23	4.2
Trail2	23.03.23			19.04.23	4.3
Trail3	23.03.23			19.04.23	4.40

Table no:4.10 Spilt tensile test for mix 1

Size of the cube	**Date of the casting**	**Date oftest**	**Date oftest**	**Date oftest**	**Split tensile strength(N/mm2)**
		7days	14 days	28days	
Trail 1	23.03.23	30.03.23			2.41
Trail2	23.03.23	30.03.23			2.42
Trail3	23.03.23	30.03.23			2.44
Trail 1	23.03.23		06.04.23		3.67

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Trail2	23.03.23		06.04.23		3.68
Trail3	23.03.23		06.04.23		3.69
Trail 1	23.03.23			19.04.23	4.91
Trail2 Days	23.03.23			19.04.23	4.92
Trail3	23.03.23			19.04.23	4.93

Table no:4.11 Spilt tensile test for mix 2

Size of the cube	**Date of the casting**	**Date oftest**	**Date oftest**	**Date oftest**	**Split tensile strength(N/mm2)**
		7days	14 days	28days	
Trail 1	23.03.23	30.03.23			2.5
Trail2	23.03.23	30.03.23			2.6
Trail3	23.03.23	30.03.23			2.7
Trail 1	23.03.23		06.04.23		3.7
Trail2	23.03.23		06.04.23		3.8
Trail3	23.03.23		06.04.23		3.90
Trail 1	23.03.23			19.04.23	4.3
Trail2	23.03.23			19.04.23	4.4
Trail3	23.03.23			19.04.23	4.50

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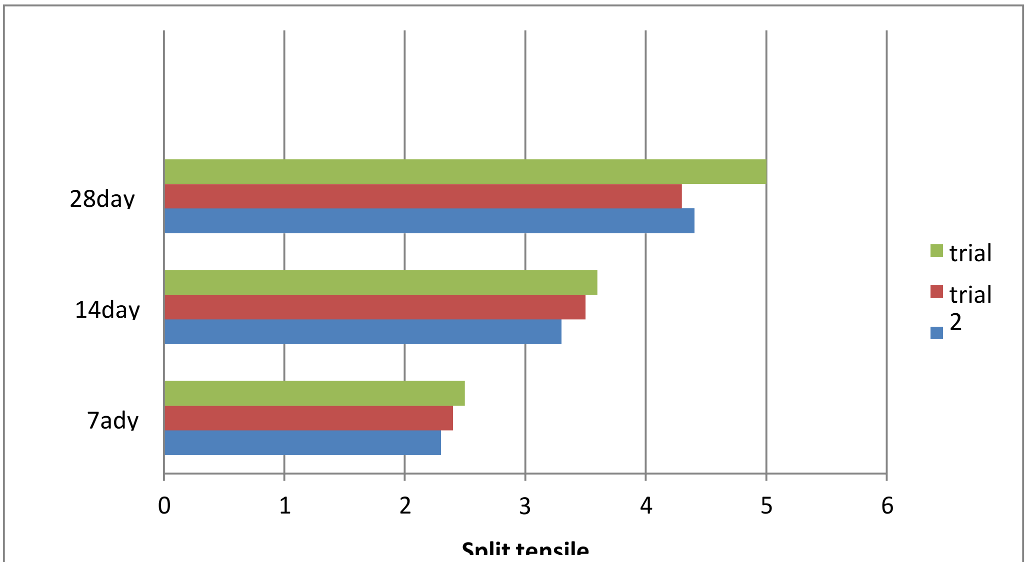

Fig no:4.9 Split tensile strength for mix 1

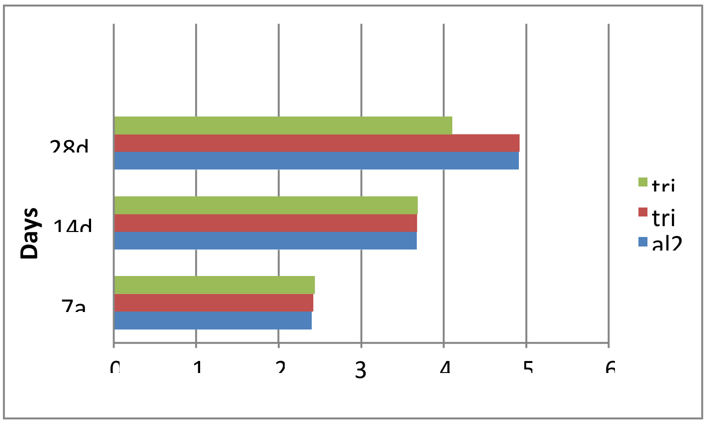

Fig no:4.10Split tensile strength for mix 2

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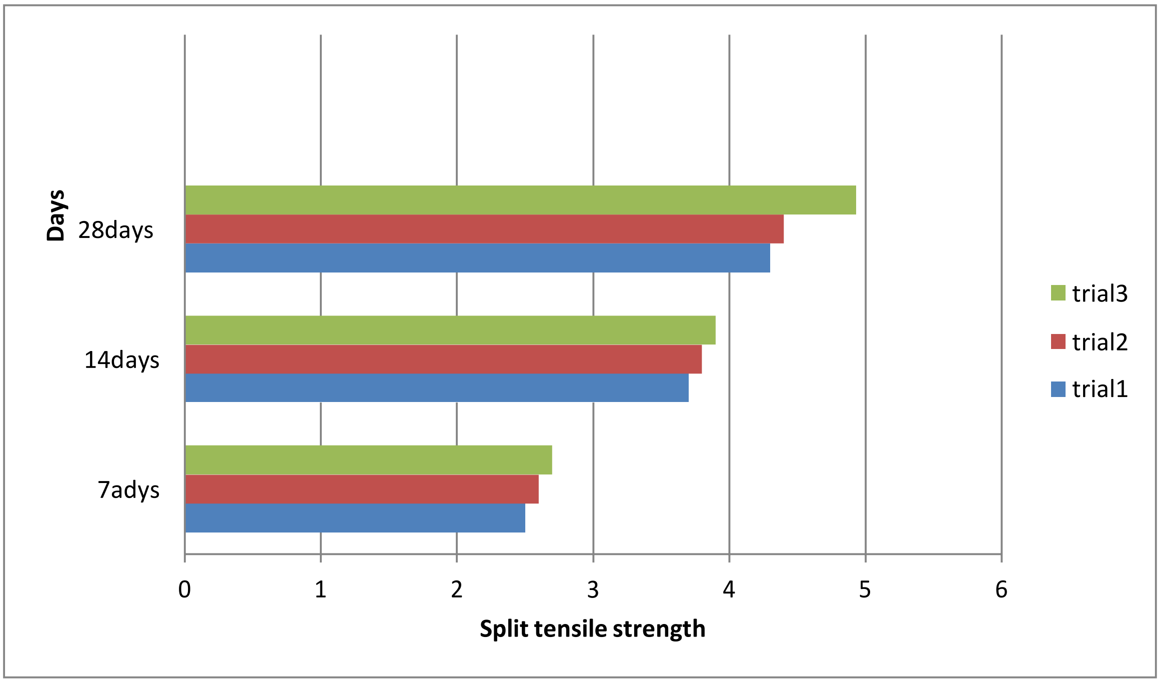

Fig no:4.11 Split tensile strength for mix 3

CONCLUSION

This experimental study has proved to be better way to disposal of steel slag.The replacement of coarse aggregate with steel slag has increased the compressive strength, split tensile strength and flexural strength of concrete.When this optimized value will be used, it will give good strength more durable concrete when compared to conventional concrete and saves material cost up to 10%. The compressive strength of the new concrete increased with the increase in copper slag content up to a replacement level of 25, maximum compressive strength of concrete increased by 25 replacement of fine aggregate by copper slag.The tensile strength of the new concrete has increased up to a replacement percentageof 40%, maximum tensile strength of the new concrete increased by 33% at 40% replacement of fine aggregate by copper slag and steel slag.Beyond the replacement level of 40% of fine aggregate with copper slag in concrete,a decrease in strength was observed. The compressive strength values are increase slightly with increasing of steel slag. The split tensile strength values are increasing slightly with increase of steel slag.

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