ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Mechanical Properties of Concrete with Fine Aggregate Partially and Fully Replaced With Copper Slag

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ABSTRACT

Characteristic assets are draining worldwide while in the meantime the created wastes from the industries are expanding generously.

The manageable improvement for development includes the utilization of nonconventional and imaginative materials, and reusing of waste materials with a specific end goal to repay the absence of common assets and to discover elective ways saving nature. So experimental examination completed to assess the mechanical and durable properties of solid blends in which fine aggregates (sand) was replaced with Copper Slag. The fine aggregates (sand) was replaced with rates 0% (for the ostensible blend), 10%, 20%, 30%, 40%, 50%, 60%,70%, 80%,90% and 100% of Copper Slag by weight. Tests were performed for properties of new concrete and Hardened Concrete. Compressive strength and Flexural strength, split tensile strength, sorptivityand RCPTwere resolved at 7, 28 and 56days.

The outcomes demonstrate that workability increments with expansion in Copper Slag rate. Test results demonstrate critical change in the strength properties of plain concrete by the incorporation of up to 80% Copper slag as substitution of fine aggregates (sand), and can be successfully utilized as a part of basic concrete. Likewise as rate of Copper Slag expanded the thickness of concrete expanded. The workability of concrete increased with expansion in rate of copper slag. Durability of copper slag is observed to be more, which increases the compressive and flexural strength of concrete.

Introduction

Research concerning the utilization of by products and mechanical squanders to enlarge the properties of concrete has been continuing for a long time. In the late decade, the endeavors have been made to use industry by-items, for example, fly ash , silica fume, ground granulated impact heater slag (GGBFS) [1], glass cullet, and so on., in the common developments. The potential utilization of modern by-items in concrete as halfway total substitution or as fractional bond substitution (partial or fully replacement), contingent upon their synthetic synthesis and molecule size. The utilization of these materials in concrete emerges because of ecological requirements, in the sheltered transfer of these by items.

Enormous consideration is being centered around the earth and protecting of regular assets and reusing of squanders materials. Really numerous commercial enterprises are delivering countless which join scrap (deposits). In the most recent 20 years, a ton of works concerning the utilization of a few sorts of urban squanders in building materials industrials process have been distributed. Numerous specialists have been stretched out to concentrate new sorts of squanders to examine profoundly specific angles [2]. The expansion of squanders, aside from the natural advantages, additionally delivers great impacts on the properties of definite items.

Cite this article as: O.Sivaiah & Dr.K.Rajasekhar, "Mechanical Properties of Concrete with Fine Aggregate Partially and Fully Replaced With Copper Slag", International Journal & Magazine of Engineering, Technology, Management and Research, Volume 5 Issue 6, 2018, Page 179-186.

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Aggregates are the fundamental element of concrete involving around 70-80% of its volume and straightforwardly influencing the fresh and harden properties. The accessibility of good quality aggregates is exhausting step by step because of huge development in Indian development industry. Concrete being the biggest man made material utilized on earth is ceaselessly requiring great nature of totals in extensive volumes. A need was felt to recognize potential option wellspring of aggregate to satisfy the future development desire of Indian development industry [3].

Copper slag

Copper slag, which is created amid pyrometallurgical generation of copper from copper minerals contains materials like iron, alumina, calcium oxide, silica and so on. For each ton of metal creation around 2.2 ton of slag is produced. Dumping or transfer of such immense amounts of slag cause natural and space issues. Amid the previous two decades endeavors have been made by a few agents and copper delivering units everywhere throughout the world to investigate the conceivable use of copper slag. The good physico-mechanical qualities of copper slag can be used to make the items like bond, fill, weight, grating, total, material granules, glass, tiles and so on separated from recouping the significant metals by different extractive metallurgical courses. This paper gives an audit of qualities of copper slag and additionally different procedures, for example, pyro, hydro and mix of pyro-hydrometallurgical strategies for metal recuperation and arrangement of worth included items from copper slag [4-7].

Physical and chemical properties of copper slag

Composition	% By mass
Fe_2O_3	55–60
Fe_3O_4	<10
SiO_2	27–33
CaO	1–3.5
S	0.2–1.5
Cu	<1
Al_2O_3	<3

Specific gravity (SSD): 4.12, Bulk density (SSD): 2.31 g/cc Fineness modulus: 3.4, Deleterious Materials: Not present

MECHANICAL WASTE AGGREGATES

A wide order of modern waste total can be made relying upon the compound way of squanders. Some waste totals originate from creation and utilization of natural materials. Plastics, elastic, calfskin and some nourishment commercial enterprises squanders are natural squanders. Then again, modern slags, mining squanders, coal industry squanders and others are inorganic squanders. Glass fortified plastics and some modern slime may contain both natural and inorganic materials. Another arrangement of modern waste total should be possible relying upon the heaviness of waste totals [6]. A few totals are lightweight by nature. Plastics, elastic, most nourishment and farming commercial ventures squanders and coal base powder are of this kind. Then again, the majority of the modern slags are heavier than customary totals.

Coal Ash as an Aggregate in Concrete

Blazing of coal produces two sorts of waste materials: fly fiery debris and base powder. There are two sorts of base cinders, wet base evaporator slag and dry base fiery debris relying upon both the kettle sort and its configuration. Coal fly powder, otherwise called pummeled fuel fiery remains, is the finest part of these cinders, which are discharged from burning chamber and transported by vent gasses. Fly cinder contains the non-flammable matter in coal alongside a little measure of carbon that remaining parts from fragmented coal burning. Fly fiery remains comprises generally of sediment measured and mud estimated shiny circles [8].

Base slag is delivered as a granular material and expelled from the base of dry boilers. Evaporator slag, a coarse grained item, is delivered from two sorts of wet base boilers, slag-tap and tornado boilers. The slag-tap evaporator blazes pounded coal while the violent wind heater smolders smashed coal. Both evaporator sorts have a strong base with a hole that can be opened to permit liquid fiery remains to stream into a container, which contains extinguishing water. At the point when the liquid slag interacts with the extinguishing water, the fiery remains cracks in a flash, takes shape, and

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International Journal & Magazine of Engineering, Technology, Management and Research
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structures pellets. High weight water planes wash the kettle slag from the container into a sluiceway, which then transmits the cinder to accumulation bowls for dewatering and further handling. Kettle slag is a coarse, rakish, smooth, dark material [9].

Dry Bottom Ash

The properties of CBA rely on upon the blazing proficiency, the technique by which the CBA is gotten and the kind of burning and in this way the physical properties of base fiery debris incredibly shift in reported works. The thickness parameters of CBA are extensively lower than those of characteristic sand (2.6 g/cm3) and in this way CBA can be utilized as lightweight total as a part of cement. CBA with generally low thickness or particular gravity is frequently demonstrative of the nearness of permeable particles. Base fiery debris with generally high particular gravity (above 3.0) may demonstrate the nearness of high measures of iron. The base powder is a permeable material and by and large has high water retention limit. Nonetheless, variety in water retention limit in various CBA is entirely extensive, with a scope of 2–32 %. The dampness substance of base fiery remains utilized by Andrade et al. (2009) as a fine total in cement is around 55 %. Then again, CBA is more fragile than normal sand and has a more noteworthy likeness to bond clinker (Rogbeck and Knutz 1999). The porosity and void substance of CBA are for the most part higher than in normal total and in this way CBA can oblige a high measure of water in a solid blend. In this manner there is some trouble in deciding the careful water/bond proportion of cement blends containing CBA [10].

Boiler Slag or Wet Bottom Ash

Evaporator slag is a vitrified material, which is an extremely sturdy and earth stable shape that for all time immobilizes its concoction constituents into the shiny formless structure. Kettle slag is made of permeable, shiny, rakish, uniform measured smooth granular particles [11]. The extinguished slag turns out to be fairly vesicular or permeable if gasses are caught in the slag. Heater slag produced from blazing of lignite or sub-bituminous coal has a tendency to be more permeable than that of bituminous coals (Lovell and Te-Chih 1992). The evaporator slag fundamentally contains particles, which can be viewed as singlesized coarse to fine sand with 90–100 % passing a 4.75 mm network sifter, 40–60 % passing a 2.0 mm network, 10 % or less passing a 0.42 mm cross section and 5 % or less passing a 0.075 mm network (Majizadeh et al. 1979). Evaporator slag is dark in shading, hard, and tough with an imperviousness to surface wear. Kettle slag regularly contains 40–60 % SiO_2, 18–38 % Al_2O_3, 2–7 % Fe_2O_3, 1–4 % CaO, 0.5–3.0 % MgO and 0.5–2.0 % TiO_2. The synthetic structure of kettle slag is additionally administered by the coal source. Heater slag shows less scraped area and soundness misfortune than base fiery debris as a consequence of its polished surface composition and lower porosity.

Industrial Slag

Slag is an in part vitreous by-result of purifying mineral because of isolating of the metal division from the useless portion. It can be viewed as a blend of metal oxides; be that as it may, slags can contain metal sulfides and metal molecules in the basic structure.

Ferrous Slag

Ferrous slag is delivered amid the generation of iron utilizing impact heater (impact heater slag) and in the partition of the liquid steel from polluting influences in steel-production heaters (steel slag).

Steel Slag

Steel slag is created amid the detachment of liquid steel from pollutions in steel heaters. The slag happens as a liquid fluid and is a perplexing arrangement of silicates and oxides that cements after cooling. There are a few unique sorts of steel slag delivered amid the steel-production process out of which fundamental oxygen heater steel slag (BOF slag), electric bend heater slag (EAF-slag) and scoop heater slag (LDF-slag) or refining slag are critical [12]. An electric circular segment heater produces steel by dissolving reused steel scrap, utilizing heat created by a curve, made by a vast electric current.

The slag is shaped through the expansion of lime, which is intended to expel debasements from inside the steel. Slag has a lower thickness than steel and consequently glides on top of the liquid shower of steel. In the fundamental oxygen process, hot fluid impact heater metal, scrap and fluxes, which comprise of lime (CaO) and dolomitic lime (CaO.MgO), are raced into the heater.

MATERIALS

Constituent materials used to make concrete can have a significant influence on the properties of the concrete. The following sections discuss constituent materials used for manufacturing of both conventional concrete (CC) and copper slag (CS) based concrete. Chemical and physical properties of the constituent materials are presented in this section.

Cement

Ordinary Portland Cement 53 grade (Penna) was used corresponding to IS 12269 (1987). The chemical properties of the cement as obtained by the manufacturer are presented in the Table 3.1.

Table 3.1. Chemical composition of cement

Particulars	Test result	Requirement as per IS:12269-1987
Chemical Composition		
% Silica(SiO_2)	**19.79**	
% Alumina(Al_2O_3)	**5.67**	
% Iron Oxide(Fe_2O_3)	**4.68**	
% Lime(CaO)	**61.81**	
% Magnesia(MgO)	**0.84**	Not more Than 6.0%
% Sulphuric Anhydride (SO_3)	**2.48**	Max. 3.0% when $C_3A>5.0$ Max. 2.5% when $C_3A<5.0$
% Chloride content	**0.003**	Max. 0.1%
Lime Saturation Factor CaO- $0.7SO_3/2.8SiO_2+1.2Al_2O_3+0.65Fe_2O_3$	**0.92**	0.80 to 1.02
Ratio of Alumina/Iron Oxide	**1.21**	Min. 0.66

Summary of physical properties and various tests conducted on cement as per IS 4031(1988) are presented in the Table 3.2.

Table 3.2 Physical Properties of Cement

Physical properties	Test result	Test method/ Remarks	Requirement as per IS 12269 (1987)
Specific gravity	3.15	IS 4031(1988) – part 11	-
Fineness (m^2/Kg)	311.5	Manufacturer data	Min.225 m^2/kg
Normal consistency	30%	IS 4031 (1988)- part 4	-
Initial setting time (min)	90	IS 4031 (1988)- part 5	Min. 30 min
Final setting time (min)	220	IS 4031 (1988)- part 5	Max. 600 min
Soundness Lechatelier Expansion (mm) Autoclave Expansion (%)	 0.8 0.01	Manufacturer data	 Max. 10 mm Max. 0.8%
Compressive strength (MPa) 3 days 7 days 28 days	 25 39 57	IS 4031 (1988)- part 6	 27 MPa 37 MPa 53 MPa

Coarse aggregate

Crushed granite stones of size 20 mm and 10 mm are used as coarse aggregate. The bulk specific gravity in oven dry condition and water absorption of the coarse aggregate 20 mm and 10mm as per IS 2386 (Part III, 1963) are 2.6 and 0.3% respectively. The bulk density, impact strength and crushing strength values of 20 mm aggregate are 1580 kg/m3, 17.9% and 22.8% respectively. The gradation of the coarse aggregate was determined by sieve analysis as per IS 383 (1970) and presented in the Tables 3.3 and 3.4. The grading curves of the coarse aggregates as per IS 383 (1970) are shown in Figs.

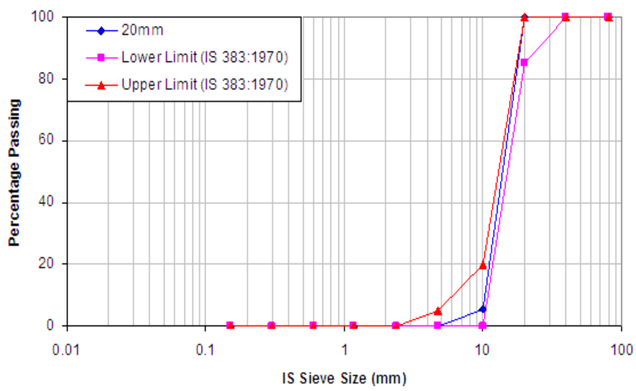

Fig. 3.1 Grading curve of 20 mm coarse aggregate

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

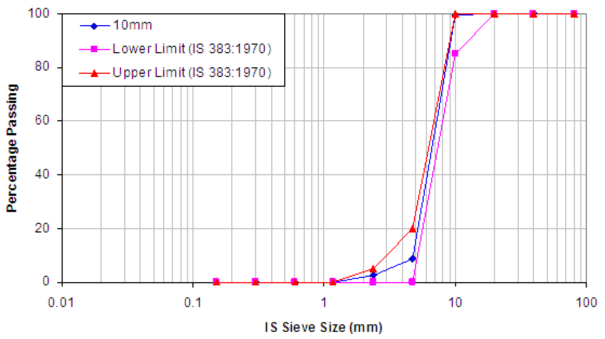

Fig. 3.2 Grading curve of 10 mm coarse aggregate

Fine aggregate

Natural river sand is used as fine aggregate. The bulk specific gravity in oven dry condition and water absorption of the sand as per IS 2386 (Part III, 1963) are 2.6 and 1% respectively. The gradation of the sand was determined by sieve analysis as per IS 383 (1970) and presented in the Table 3.5. The grading curve of the fine aggregate as per IS 383 (1970) is shown in Fig. 3.3. Fineness modulus of sand is 2.26.

Table 3.5. Sieve analysis of fine aggregate

Sieve No.	Cumulative percent passing	
	Fine aggregate	IS: 383-1970 – Zone III requirement
3/8" (10mm)	100	100
No.4 (4.75mm)	100	90-100
No.8 (2.36mm)	100	85-100
No.16 (1.18mm)	99.25	75-100
No.30 (600µm)	65.08	60-79
No.50 (300µm)	7.4	12-40
No.100 (150µm)	1.9	0-10

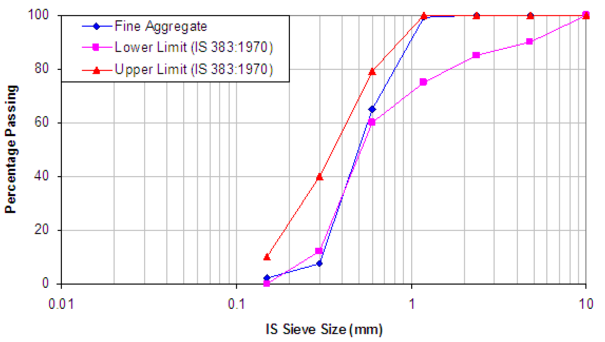

Fig. 3.3 Grading curve of fine aggregate

Water

Generally, water that is suitable for drinking is satisfactory for use in concrete. When it is suspected that water may contain sewage, mine water, or wastes from industrial plants or canneries, it should not be used in concrete unless tests indicate that it is satisfactory. Water from such sources should be avoided.

Copper slag

Copper slag is a by-product obtained during the production of copper. The slag is a black glassy and granular in nature and has a similar particle size range like sand which can be used as a replacement of sand. Copper slag used in this work was brought from Sterlite industries (India) Ltd, Tuticorin.

Fig 3.4 copper slag

COMPRESSIUON TEST

One of the most important properties of concrete is the measurement of its ability to with stand compressive loads. This is referred to as a compressive strength and is expressed as load per unit area. One method for determining the compressive strength of concrete is to apply a load at a constant rate on a cube (150×150×150 mm), until the sample fails. The compression tests performed in this project were completed in accordance with IS standard 516 “Methods of Tests for Strength of Concrete”.

The apparatus used to determine the compressive strength of concretes in this experimental work was a

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
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universal testing machine (UTM). For this study samples were tested for compression testing at 7, 28, 56 days of curing. The compressive strength of the concrete in terms of pressure was then calculated using the Equation

fc=P/A

Where,

fc = Compressive Strength of Concrete, (Kpa or psi)

P = Maximum load applied (KN or lb), and

A = The cross-sectional area of sample (mm2 or in2)

Fig 3.1.1 Compression testing machine (CTM)

SPLIT TENSILE STRENGTH

The split tensile strength at which failure occurs is the tensile strength of concrete.

In this Investigation the test is carried out on cylinder by splitting along its middle plane parallel to the edges by applying the compressive load to opposite edges as per IS: 516-1959 [12].

The arrangement for the test is as shown in fig.

The split tensile strength of cylinder is calculated by the following formula.

Experimental test results are shown in Table

Ft = 2P/3.14DL

Where,

Ft = Split tensile strength (N/mm2),

P = Load at Failure (N),

L = Length of Cylinder (mm),

D = Diameter of cylinder (mm).

Fig 3.1.3 Split tensile set up in CTM

Fig 3.1.4 After applying load

RESULTS

Compressive strength

Table 4.1 shows the compressive strength values of concrete with partial replacement of Copper slag

Table 4.1 Compressive strength of concrete

Mix	7days	28days	56days
NORMAL	27.56	37.78	37.84
CS 10 %	30.73	40.97	39.10
CS 20 %	36.33	48.13	49.37
CS 30 %	33.27	40.83	45.47
CS 40 %	28.43	38.80	44.43
CS 50 %	28.87	39.43	44.90
CS 60 %	29.53	43.33	45.17
CS 80 %	28.01	35.17	38.43
CS 100 %	22.30	32.07	35.70

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
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From the results it is seen that the concrete mixes with partial replacement of copper slag have attained higher values of compressive strength at all ages as compared to that of conventional concrete (CS-0) as shown in Fig.4.1.

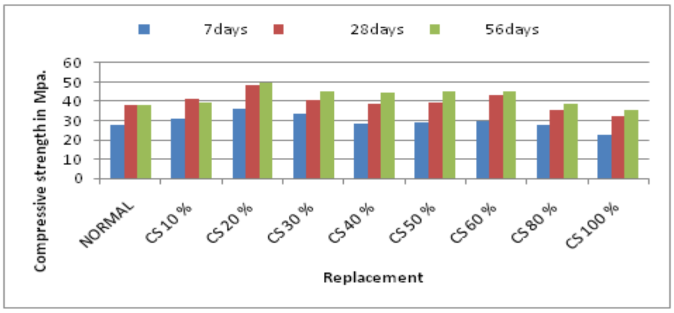

Fig 4.1 compressive strength

Maximum Compressive strength of concrete for a replacement of fine aggregate by 20% of copper slag increased by 34% at 7 days and increased by 29% at 28 days. Similar increase is observed at 56 days strength. Replacement of copper slag up to 80% will increase the strength of design mix, but beyond 80% replacement the strength started to reduce. The strength at 100 % replacement is reduced by 7% at 28 days.

Splitting tensile strength

Table 4.2 shows the splitting tensile strength (STS) values of concrete with partial replacement of Copper slag

Table 4.2 Splitting tensile strength of concrete

MIX PROPORTIONS	SPLIT TENSILE STRENGTH(Mpa)
CS 0%	4.14
CS10%s	4.17
CS20%	4.09
CS30%	4.32
CS40%	4.12
CS50%	4.12
CS60%	4.08
CS70%	4.41
CS80%	4.14
CS90%	4.11
CS100%	4.06

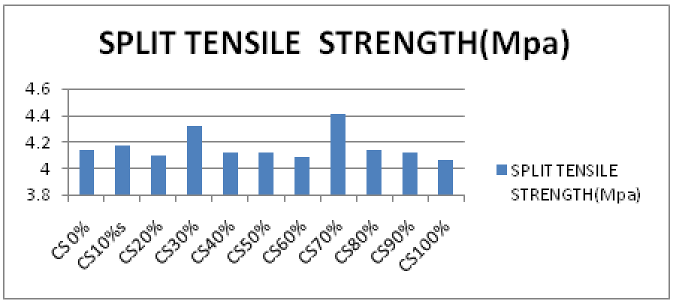

Fig. 4.2 Splitting tensile strength of mixes for 28 days

From the results it is seen that the concrete mixes with partial replacement of copper slag have attained almost equal values of STS at all ages as compared to that of conventional concrete (CS-0) as shown in Fig. 4.2. It is clearly observed that as replacement of copper slag increased at 30% and 70%, the STS values are found to be almost equal to the CC. The STS values of the concrete mixes CS_30 and CWR_70 are comparable to that of M 25 grade of CC at all ages. The further increase in replacement of CS decreased the STS values significantly as in the case of the concrete mixes CS_20 and CS_30. Hence, it can be recommended to use CS at 70% partial replacement of fine aggregate in order to attain the desired values of CC.

CONCLUSIONS

1) Greatest Compressive strength of concrete for a substitution of fine aggregates by 20% of copper slag increased at 7 days
2) Compressive strength increased by 29% at 28 days. Comparable expansion is seen at 56 days strength.
3) Replacement of copper slag up to 80% will increases the strength of design mix.
4) After that80% substitution the strength began to decrease.
5) The strength at 100 % substitution is decreased by 7% at 28 days.
6) It is observed that, the flexural strength of concrete at 28 days is higher than configuration design mix (without substitution) for 20% substitution of fine aggregates by Copper slag.
7) The flexural strength of concrete is expanded by 14%. This likewise shows flexural strength is more for all rate substitutions than configuration design mix.

8) Compressive strength and Flexural strength was found to be increased because of the high sturdiness property of Copper slag.
9) Chloride penetrability of the concrete observed as moderate.
10) The sorpitivity and water absorptions values are observed as increased with increase in amount of copper slag.

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