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Use of Copper Slag as Fine Aggregate in Concrete: A review

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Abstract: In India, there is large demand of aggregates mainly from civil engineering industry for the construction of road and concrete. But now a days, it is very difficult problem for available for fine aggregate. The construction industry is the only area where the safe use of waste material (Copper Slag) is possible. Various studies have been conducted to reduce effect on environment, reduce cost of concrete, using by products like copper slag as partial replacement of fine aggregate is one of the best method in reducing the impacts. The many authors have also revealed numerous uses of copper slag as a replacing agent in determining the strength of concrete. A thorough review of copper slag and its properties is been carried out in this paper. The purpose of the investigation is to analyse the behaviour of concrete while replacing the copper slag with different proportions of fine aggregate in concrete. During the past two decades attempts have been made by several investigators and copper producing units all over the world to explore the possible utilization of copper slag. Keywords: Copper slag, fine aggregate, cement, concrete

I. INTRODUCTION

Many countries are witnessing a rapid growth in the construction industry, which involves the use of natural resources for the development of infrastructure. The authors developed waste management strategies to apply for replacement of fine aggregate for specific need. The construction industry is the only area where the safe use of waste material (Copper Slag) is possible, Copper Slag reduces environment pollution, space problem and also reduces the cost of concrete. Copper Slag were generated as a by-product of Copper processing ,in which mostly ended up as land fill though some amount of Copper Slag are used in the application of abrasives in the process of rust removal. It contains large amount of Iron Oxide and Silicate. Its physical properties are similar of natural sand. The chemical traces such as Copper, Sulphate & Alumina present in the Slag are not harmful. Copper slag is the waste material of refining of copper and matte smelting such that each ton of copper generates approximately 2.5 tons of copper slag.

Copper slag is one of the materials that are considered as a waste which could have a promising future in construction Industry as partial or full substitute of aggregates. Copper Slag is used to increase the strength of concrete and reduces the environmental pollution, space problem and also reduces the cost of concrete. Copper slag has also gained popularity in the building industry for use as a fill material. Contractors may also use copper slag in place of sand during concrete construction. Copper slag can also be used as a building material, formed into blocks. Copper slag is widely used in the sand blasting industry and also in the manufacture of abrasive tools .Large quantities of waste materials are being generated by various industries and disposal of waste materials is causing environmental and health hazards. For many years, Industrial by-products such as fly ash, silica fume and slag were considered as waste materials. Application of these materials as replacement for cement and sand in Concrete showed improvement in workability and durability compared to normal concrete and has found their application in the many structures.

In the recent past, intensive research studies have been carried out to explore all possible recycling and reuse methods. Construction waste, blast furnace Slag, steel slag, coal fly ash and bottom ash have been accepted in many places as alternative aggregates in embankment, roads, pavements foundation and building construction, raw material in the manufacture of ordinary Portland cement as pointed out by Teikthyeluin et al (2004). The world copper production is currently about 14.98 million tonnes (International Copper Study Group, 2005) and it is estimated that for every tonne of copper produced, about 2.2 tonnes of copper slag is generated as a waste . Around 24.6 million tons of Copper slag is generated from the world copper industry (Gorai et al 2003). Though some portion of copper slag is widely used in the sand blasting and in the manufacturing of abrasive tools, the remainder is disposed of without any further reuse or reclamation. The use of copper slag in the concrete as a replacement for fine aggregate, reduces the costs of disposal, lowers the cost of the concrete and also helps in protecting the environment. Despite the fact that several studies have been reported on the effect of copper slag on the properties of Concrete, further investigations are necessary in order to obtain a comprehensive understanding that would provide an engineering base to allow the use of copper slag in concrete.



II. MATERIAL PROPERTIES

A. Cement

Ordinary Portland cement of 43 grades confirming to IS 8112:1989 is used. The Properties of Cement are shown in Table 1.

Sr. No.	Test	Results	Specified by IS 8112:2013
1	Fineness of cement (kg/m2)	245	225
2	Consistency of cement	36	30
3	Initial setting time (minutes)	75	30
4	Final setting time (minutes)	260	600
5	Specific gravity	3.12	2.5-3.5
6	Compressive strength (N/mm2)	48.3	58
7	Soundness (mm)	3	10

Table 1: Physical properties of cement

B. Fine Aggregate

Fine aggregates are obtained after sieve of sand which passed through 4.75mm. The fineness modulus of sand is 3.30% and specific gravity is 2.74

C. Coarse Aggregate

The Coarse aggregate are obtained from a local quarry. The coarse aggregate is used with size between 10mm to 20mm having a specific gravity 2.74 and fineness modulus of 5.9%.

D. Copper Slag

Copper slag is a by-product of copper obtained during the matte smelting and refining of copper. Copper slag is an irregular, granular in nature, glassy and black and its properties are similar to the river sand. In this project, Copper slag used is brought from Sterile Industries India Ltd, Tuticorin. Every ton of copper will generate approximately 2.5 tons of copper slag. (Sterlite Industries India Ltd produces 400,000t/year of copper and during the process, around 800,000t of copper slag is generated in a year (Al-Jabri, et al 2009).



Figure 1. Copper slag

E. Production of Copper Slag

Exploitage of copper slag in uses such as Portland cement substitution and/or as aggregates has threefold advantages of eliminating the costs of dumping, reducing the cost of concrete, and minimizing air pollution problems (Kharade et al., 2013). The researchers related the physical and chemical properties of copper slag given in Table 2 and Table 3, respectively.



Physical properties	Physical component
Particle shape	Irregular
Appearance	Black & glassy
Туре	Air cooled
Specific gravity	3.91,3.68
Percentage of voids	43.20%
Bulk density	2.08 g/cc, 1.70 to 1.90 g/cc
Fineness modulus of copper slag	3.47
Angle of internal friction	51° 20'
Particle size	0.075 mm to 4.75 mm
Hardness	Between 6and 7

Toble 2	Dhusical	proportion	of connor	clog (Chookalingam	at al (2012)
	rnysicai	properties	or copper	siag (Chockanngann	et al., 2013)

Table 3:	Chemical	composition	of	copper	slag
1 uoie 5.	chenneur	composition	or	copper	Siug

1	11 0
Component	Copper slag (%)
Silica (sio ₂)	33.05
Alumina (Al ₂ so ₃)	2.79
Iron oxide (Fe ₂ o ₃)	53.45
Calcium oxide (Cao)	6.06
Calcium oxide (Cao)	1.56
Sulphuric trioxide (so ₃)	1.89

- F. Use of Copper Slag In Concrete
- 1) Cost of Concrete production is reduced when Copper Slag is used as a fine aggregate in concrete.
- 2) High toughness of Copper Slag contributes to Increased Compressive strength.
- 3) Due to low water absorption and due to glassy surface of Copper slag the workability of concrete is increased with increase of Copper Slag content in the concrete mixture.
- 4) Use of copper slag has helped in waste management and dumping of industrial wastes.
- 5) Copper Slag has similar properties as river sand as it contains silica (SiO₂) similar to sand.
- 6) Addition of Copper slag increases then the density of concrete there by enlargement the self-weight. $\$

Sr. No.	Authors	Title	Conclusion
1	Al-Jabri et al (2009)	Copper slag as	The results indicate that there is a slight increase in
		sand replacement	the HPC density of nearly 5% with the increase of
		for high	copper slag content, whereas the workability
		performance	increased rapidly with increases in copper slag
		concrete	percentage. Addition of up to 50% of copper slag as
			sand replacement yielded comparable strength with
			that of the control mix. However, further additions
			of copper slag caused reduction in the strength due
			to an increase of the free water content in the
			mix[1].
2	Caijun Shi et al (2008)	Utilization of	The authors concluded that the utilization of copper
		copper slag in	slag in cement mortar and concrete is very effective
		cement and	and beneficial for all related industries, particularly
		concrete	in areas where a considerable amount of copper slag
			is produced. It proved both environmental as well as
			technical benefits. They observed that there was

III. LITERATURE REVIEW



			more than 70% improvement in the compressive
			strength of mortars with 50% copper slag
			substitution[2].
3	Chavan et al (2013)	Performance of	In this research paper, M25 grade of concrete was
		Copper Slag on	used and tests were conducted for various
		strength properties	proportions of copper slag replacement with sand of
		as partial replace of	0 to 100% in concrete and observed that the
		Fine Aggregate in	maximum compressive strength of concrete
		concrete mix	increased by 55% at 40% after replacement of fine
		design	aggregate by copper slag, and up to 75%
			replacement, the concrete gain more strength than
			control mix concrete strength[3].
4	Harsha et al (2015)	Performance of	The percentage replacement of sand by granulated
		Concrete by	copper slag were 0%,10%,20%,30%,40%,50%,60%
		Copper Slag as	and 70%. Required numbers of cubes, cylinders,
		Partial	beams were cast for grades of M30. Curing should
		Replacement of	be done for a period of 7, 28 days of hydration with
		Fine Aggregates	partial replacement of sand by Copper slag. The
			experimental investigation showed that percentage
			replacement of sand by copper slag shall be up to
			60%[4].
5	Kayathri et al (2014)	Effect of Copper	In this paper fine aggregate (sand) was replaced
		Slag, Fly Ash and	with four different percentages (0%, 25%, 50% and
		Granite Power as a	75%) of fly ash, copper slag and granite powder by
		Partial	weight. Tests were performed for properties of fresh
		Replacement in	concrete. Compressive strength, split tensile
		Fine Aggregate	strength were determined at 7, 14 and 28days. It is
			concluded that the strength of concrete is
			determined by the properties of Copper slag,
			Granite powder. The compressive strength of
			various mixes of Copper slag, Granite powder, and
			Fly ash fiber in concrete at 28days will be 51.8
			N/mm ² [5].
6	Khanzadi et al (2009)	Mechanical	The percentages of the cement replacements by
		properties of high	silica fume were 0%, 6%, and 10%. The use of
		strength concrete	copper slag aggregate compared to limestone
		incorporating	aggregate resulted in a 28-day compressive strength
		copper slag as	increase of about $10-15\%$, and a splitting tensile
		coarse aggregate	strength increase of 10–18%. It can be concluded
			trom the results of this study that using copper slag
			as coarse aggregate in high-strength concrete is
	I D D (20)		technically possible and useful[6].
7	Kumar & Ramana (2015)	Use of Copper Slag	In this paper, five mixes containing different
		and Fly Ash in	proportions of copper slag ranging from 0% (for the
		High Strength	control mix) to /5%. Five mixes containing fly ash
		Concrete	as partial replacement of cement ranging from 6%
			to 30% (all 5 mixes contains 50% copper slag as
			sand replacements). Concrete mixes were tested for
		1	workability, density, compressive strength, tensile



			strength, flexural strength. The results indicate that
			it is recommended that 50% of copper slag can be
			used as replacement of sand and 18% fly ash can be
			used as replacement of cement in order to obtain
			high strength concrete[7].
8	Ahmad et al(2017)	Experimental study	The present investigation is carried out for
_		on the behaviour of	M-40 grade of concrete mixes with Partial
		copper slag as	replacement of Fine Aggregate (Sand) by Copper
		partial replacement	Slag in proportions of 0% , 10% , 20% , 30% , 40% and
		of fine aggregate in	50% The result indicates the maximum strength was
		concrete	achieved for 10 % replacement of fine aggregate
		concrete.	with copper slag Further addition of copper slag
			reduces the strength[8]
0	Madhavi (2014)	Copper slag in	This paper studies the effect of replacement of Fine
,	Wiadila VI (2014)	concrete as	aggregate with copper slag on mechanical
		raplacement	properties of concrete Copper slag which is an
		motorial	industrial waste product can be used as replacement
		material	for compart and cond and contributes to the increase
			in various mechanical properties of concrete
			Copper slag can be used up to 20% but when used
			beyond 50% results in decrease in strengths[0]
10	Madhagwaran at al (2014)	Studios on uso of	It is suggested that the conner slog can be used for
10	Mauneswaran et al (2014)	Copper Slag as	n is suggested that the copper stag can be used for plastering of floorings and horizontal up to 50 % by
		Copper Stag as	plastering of hoorings and horizontal up to 50 % by
		Material for Diver	mass of the line aggregate, and for vertical surfaces,
		Sond in Duilding	Such as, blick/block wans it can be used up to 25 %.
		Sand in Building	In this study on concrete mixtures were prepared
		Constructions	with two water cement ratios and different
			proportions of copper stag ranging from 0 % (for the control mix) to 100 % of fine accregate. The
			Concrete mixes were evaluated for workshility
			density and compressive strongth[10]
11	Innakiramajah at al	A study of concrete	The results showed that the dynamic compressive
11	(2016)	using copper slag	strength of copper slag reinforced concrete
	(2010)	as a partial	generally improved with the increase in amounts of
		replacement of fine	copper slag used as a sand replacement up to 20%
		aggregate	compared with the control concrete beyond which
		aggregate.	the strength was reduced Also investigated the
			mechanical properties of high strength concrete
			incorporating copper slag as a fine aggregate. The
			results indicated that the strength of concrete with
			less than40% copper slag replacement was higher
			than or equal to that of the control
			Specimen[11]
12	Purna (2014)	Use of Copper Slag	It is observed that there is 70% improvement in
12		as Sustainable	compressive strength with 50% replacement of
		Aggregate	compressive strength with 50% replacement of copper slag. The flexural and tensile strength were
		1.001.0000	similar to the control mix(100% sand) spending up
			to 50 % copper slag replacement of sand but
			decreased with an additional surge in conner slag
1	1	1	accreased mut an additional surge in copper slag



			contents. In the concrete mixture, workability
			increases with the increase of copper slag. It is
			suggested that 40-50% substitution of copper slag
			as aggregate (fine) produces good quality of
			concrete having good quality requirement[12].
13	Selvi P et al (2014)	Experimental	The results concluded that the compressive strength,
		Study on Concrete	split tensile strength and flexural strength of
		Using Copper Slag	concrete shown higher value at 40% replacement of
		as Replacement	fine aggregate using copper slag. So it is
		Material of Fine	recommended that 40% of fine aggregate can be
		Aggregate	replaced by copper slag. The ultrasonic pulse
			velocity test indicated the excellent quality of
			concrete at 40% replacement level[13].
14	Singh et al (2014)	Utilization of	In this study, M30 grade concrete was considered to
		Copper Slag as	study the strength parameters, compressive and
		Fine Aggregates in	flexural strength development for concrete curing
		Cement Concrete	periods of 3, 7 and 28 days. It is concluded that the
		Pavements	compressive and flexural strength increases with
			respect to the percentage replacement of copper slag
			by the weight of fine aggregate up to 40%
			replacement[14].
15	Taha et al (2011)	Effect of copper	A substitution of up to 40-50% copper slag as a
		slag as a fine	sand replacement yielded comparable strength to
		aggregate on the	that of the control mixture. However, addition of
		properties of	more copper slag resulted in strength reduction due
		cement mortar and	to the increase in the free water content in the mix.
		concrete	Also, the results demonstrated that surface water
			absorption decreased as copper slag content
			increases up to 50% replacement[15].
16	Velumani & kumar	Durability And	The author observed that the compressive strength
	(2014)	Characteristics of	on concrete increased by surrogating fine aggregate
		Copper Slag As	by 40% of copper slag. From the test results it has
		Fine Aggregate and	been founded that the average pulse velocity is
		Fly Ash as Cement	above 5 km/sec for 40% copper slag replacement
		in Concrete	with fine aggregate and 30% replacement with
			cement[16].
17	Vijaya raghavan et al	Effect of copper	From this study, it is observed that 40% of copper
	(2017)	slag, iron slag and	slag, 40% of iron slag and 25% of RCA is the
		recycled concrete	optimized replacement mix of fine and course
		aggregate on the	aggregate respectively, which highly enhances the
		mechanical	mechanical properties of concrete when compared
		properties of	with conventional concrete[17].
		concrete	*[* ·].

IV. CONCLUSION

The following conclusions may be drawn from the present study

- A. Copper slag which is an industrial waste product can be used as replacement for cement and sand and contributes to the increase in various mechanical properties of concrete. Copper slag can be used upto 30% but when used beyond 50% results in decrease in strengths
- B. Copper slag is a suitable material for replacement of fine aggregate in concrete.



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- C. Copper slag concrete showed considerable increase in strength when used with in permissible quantities.
- D. The maximum strength was achieved for 30% to 40 % replacement of fine aggregate with copper slag. Further addition of copper slag reduces the strength.
- *E.* The replacement of fine aggregate using copper slag in concrete increases the density of concrete thereby increases the self-weight of the concrete.
- *F*. The construction industry is the only area for safe use of waste materials, which reduces the environmental problems, space problems and cost of construction.
- G. Copper Slag has a potential to provide as an alternative to fine aggregate up to 30% to 40% and helps in maintaining the environmental as well as economical balance.

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