Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 9, September : 2023

A STUDY ON EFFECT OF COPPER SLAG AS A FINE AGGREGATE ON THE MECHANICAL PROPERTIES OF CONCRETE

[1]*C N NARASIMHA REDDY*,[2]*G RAJESH*
[1]*Student*,[2]*Assistant Professor*
Department of Civil Engineering
PVKK Institute of Technology (PVKKIT),Anantapuramu

ABSTRACT
An experimental investigation was conducted to study the effect of using copper slag as a fine aggregate on the properties of cement mortars and concrete. Various mortar and concrete mixtures were prepared with different proportions of copper slag ranging from 0% (for the control mixture) to 100% as fine aggregates replacement. Cement mortar mixtures were evaluated for compressive strength, whereas concrete mixtures were evaluated for workability, density, compressive strength, tensile strength, flexural strength and durability. The results obtained for cement mortars revealed that all mixtures with different copper slag proportions yielded comparable or higher compressive strength than that of the control mixture. Also, there was more than 70% improvement in the compressive strength of mortars with 50% copper slag substitution in comparison with the control mixture. The results obtained for concrete indicated that there is a slight increase in density of nearly 5% as copper slag content increases, whereas the workability increased significantly as copper slag percentage increased compared with the control mixture. A substitution of up to 40–50% copper slag as a sand replacement yielded comparable strength to that of the control mixture. However, addition of more copper slag resulted in strength reduction due to the increase in the free water content in the mix. Also, the results demonstrated that surface water absorption decreased as copper slag content increases up to 50% replacement. Beyond that, the absorption rate increased rapidly and the percentage volume of the permeable voids was comparable to the control mixture. Therefore, it is recommended that up to 40–50% (by weight of sand) of copper slag can be used as a replacement for fine aggregates in order to obtain a concrete with good strength and durability requirements.

I. INTRODUCTION

1.1. General

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), 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. The expansion of squanders, aside from the natural advantages, additionally delivers great impacts on the properties of definite items.

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.

Significant exploration is made on the utilization of various materials as total substitutes, for example, coal powder, impact heater slag, fiber glass waste materials, waste plastics, elastic waste, sintered slime pellets and others. The utilization of waste materials can be expanded complex if these are utilized as total into bond mortar and cement. This sort of utilization of a waste material can tackle issues of absence of aggregate in different development locales and lessen ecological issues identified with aggregate mining and waste materials. As the aggregates can essentially control the properties of concrete, the properties of the aggregates have an extraordinary significance. In this way an exhaustive assessment is important before utilizing any waste material as aggregates in concrete.

Contingent upon their era, wastes can be isolated into two sorts: those that specifically come about because of industry as modern by-items and those that can be named reused wates. The primary sort incorporates coal fiery debris, different slags from metal industries, modern muck, and waste from commercial enterprises like mash and paper processes, mine tailings, nourishment and agribusiness, and calfskin. The second sort incorporates distinctive plastic and elastic squanders.

Despite the fact that few waste items are being researched as aggregate options, this examination is intended to present another waste material copper slag.

1.2 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.

Copper slag is a by-item acquired amid the creation of copper. The slag is a dark shiny and granular in nature and has a comparative molecule size extent like sand which can be utilized as are arrangement of sand. Copper slag utilized as a part of this work was brought from Sterlite commercial enterprises (India) Ltd, Tuticorin

II. LITERATURE REVIEW

GENERAL

This section talks about the examination work completed on solid utilizing different modern by-items and squanders materials. This section gives a far reaching audit of the work did by different specialists in the field of reusing the mechanical by-items and squanders materials in concrete as full or halfway substitution of totals.

The quick improvement of the development business and utilization of common assets and decay of the earth in a few rising economies have brought about an unsustainable advancement of the development business. Therefore, utilizing the mechanical by-items and waste materials is a basic stride in natural manageability. Total regularly represents 65–80% of the solid volume and it assumes a significant part in solid properties, for example, workability, quality, dimensional security, and solidness. The utilization of waste materials as total in solid arrangement can devour tremendous measures of waste materials. This can take care of issues of absence of total on development destinations and diminish natural issues identified with total mining and waste transfer. There is a developing enthusiasm for utilizing waste materials as total and extensive examination has been embraced on the utilization of a wide range of materials as total substitutes.

Compelling examination is being made on the utilization of numerous materials as total substitutes, for example, coal fiery remains, impact heater slag, fiber glass waste materials, waste plastics, elastic waste, sintered slime pellets and others.

2.2. 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. 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.

C. Lavanya, A. Sreerama Rao, N. Darga Kumar

Copper Slag is a waste product coming out from the smelting process for the production of copper. Lime mixed Copper slag in various percentages gives effective and improved results of cohesion when compared to copper slag without any admixture. As the % of Lime increases from 2% to 10% the MDD values are slightly increasing. Copper slag when mixed with 2% Lime and 10% Lime, results increase in cohesion and decrease in angle of internal friction. From the results, it was noticed that an increase in cohesion is seen which is nearly 12 times when 10% lime is mixed with copper slag when it is compared with copper slag mixed with the 2% lime. Lime admixed copper slag when tested after 7 days, 14 days and 28 days of curing results improvement in cohesion and decrease in angle of internal friction as the curing period increases. When Lime mixed with CS along with soils may result in beneficial effects in terms of stabilization of clayey deposits. As a future study, the combination of CS and Cement or lime along the soil can be mixed and relevant geotechnical testing can be carried out to bring out the efficacy of CS along with the cement or lime in the soil stabilization process.

Amit S. Kharade, Sandip V. Kapadiya, Ravindra Chavan

As the percentage of Copper Slag in concrete mix increases, the workability of concrete increases. This is because copper slag is unable to absorb the water in large proportion. 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. It is observed that, the flexural strength of concrete at 28 days is higher than design mix (Without replacement) for 20% replacement of fine aggregate by Copper slag, the flexural strength of concrete is increased by 14%. This also indicates flexural strength is more for all percentage replacements than design mix. Compressive strength and Flexural strength was increased due to the high toughness property of Copper slag. As the percentage of Copper slag in design mix as replacement increases, the density of harden concrete observed to be increased. The density was increased by 7% when replacement of Fine aggregate by 100% copper slag. This is because weight of concrete increases with copper slag

H. Hanio Merinklin , S. Manjula Devi, Dr. C. Freeda Christy

A detailed review of literature has been done for copper slag, geopolymer concrete and fly ash. Physical and chemical properties of individual (fly ash, copper slag, coarse aggregate and fine aggregate) components of geopolymer concrete are found in laboratory tests and SEM Analysis is also done. Experiment investigation of strength (Compressive strength, split tension strength) for geopolymer concrete are found and listed. Test of alkalinity for conventional concrete and geopolymer are found. Test on durability of geopolymer concrete will be done.

E. Sureshkumar T. Suresh, V. Vijayan , T. Sathanandham , K. Sivanesan, S. Rathinamoorthy

The strength of the conventional concrete has attained the target strength in 7days and 28 days The self compacting concrete has obtained the grade of strength, but it does not meet the target strength

Viji C . M

The shear strength properties of the sand-copperslag mix increases with increase in the percentage of copper slag. When 30% copper slag was mixed with sand, the angle of internal friction increased from 340 to 420. The load carrying capacity of pure clay bed is 838.08N. When 30% copper slag was added the load carrying capacity increased to 1943.88N. From direct shear test and load test, the optimum percentage of copper slag was taken as 30%.

Srinivas C. H, S. M Muranal

The workability increases up to 31.57 % for 100 % replacement of copper slag as a fine aggregate fine aggregate. The maximum compressive strength of concrete increases up to 8.63 % for 20 % percentage replacement of fine aggregate, but up to 40 % percentage of copper slag can be replaced which is greater than the target strength. The maximum charge passed was 1538.5 coulombs for copper admixed concrete which is graded as per ASTM C1202 under category “low”. As such it is indicating the addition of copper slag definitely reduces the pores of concrete and makes the concrete impermeable. Accelerated corrosion test reveals that the corrosion rate of copper slag admixed concrete with rebar is increases as compared to normal concrete specimens .

Premlal. V G . A. Nizad

The strength parameters are optimum when the concrete containing 40 % replacement of fine aggregate by copper slag. Due to low water absorption, coarser & glassy surface of copper slag, the workability of concrete increases when the % of copper slag increases. High toughness of copper slag attributes to the increased compressive strength. Maximum percentage increase in compressive strength is 21.43 %. When copper slag % is greater 40, there is a reduction in compressive strength. This is due to the increased voids and increased free water content. Copper slag admixed concrete shows higher energy absorption value and this is attributed to the ductile nature of copper slag admixed beams. Maximum percentage increase in flexural strength is 22.87 %. Maximum percentage increase in split tensile strength is 32.51 %. Maximum percentage increase in modulus of elasticity is 35.52 %. It is recommended that if the copper slag admixed concrete is to be used in corroded environment, the reinforcement should be coated with some protective coating. Copper slag admixed concrete specimens showed lesser resistance to acid attack due to its higher mass and higher resistance to sulphate attack, chloride attack and carbonation. Chloride penetration of copper slag admixed concrete is graded under the category “very low”. It is indicating the lesser permeability of slag admixed concrete.

R.Vignesh, A. Nisha Devi

From the test results, it was found that the compressive strength, split tensile strength and flexural strength increases while adding 50% and 60% replacement of fine aggregate by copper slag with glass fibre. The optimum percentage of fibre to be added was found to be 0.1%.Adding 50%, 60%, 70% replacement of fine aggregate by copper slag the strength decreased. This is due to increases free water content in the mixes. The excessive free water content in the mixes with copper slag content causes the bleeding and segregation in concrete.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 9, September : 2023

With the addition of glass fibre at 50% and 60% of fine aggregate by copper slag the strength increased, because fibre reduce the permeability of concrete and thus bleeding of concrete get reduced. A reduction in bleeding improves the surface integrity of concrete, improves its homogeneity and reduces the probability of cracks. But for 70% replacement of fine aggregate by copper slag with glass fibre, the strength gets decreased when compared to conventional concrete. This is due to high workability of concrete. Flexural strength of beam is increased due to high toughness of Copper slag. The Glass fibre increases the strength of concrete with lower fibre dosage and it will be improves crack control and preserves post cracking due to the properties of glass fibre. The ultimate load carrying capacity of beam with copper slag 50% and glass fibre 0.1% beam increases by 15.7% than the controlled beam when tested at 28 days. Replacement of copper slag in fine aggregates replacement reduces the cost of making concrete and it provides additional environmental as well as technical benefits for all related industries. Based upon the results obtained it was concluded that, the replacement of copper slag by fine aggregates is possible up to 60% with intrusion of glass fibre.

III. EXPERIMENTAL PROGRAM

3.1. 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.

3.1.1 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

3.1.2. 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/m^3, 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.

Table 3.3. Sieve analysis of 20 mm coarse aggregate

Sieve size	Cumulative percent passing	
	20 mm	IS 383 (1970) limits
20 mm	100	85-100
16 mm	56.17	N/A
12.5 mm	22.32	N/A
10 mm	5.29	0-20
4.75 mm	0	0-5

Table 3.4. Sieve analysis of 10 mm coarse aggregate

Sieve size	Cumulative percent passing	
	10 mm	IS 383 (1970) limits
10 mm	99.68	85-100
4.75 mm	8.76	0-20
2.36 mm	2.4	0-5

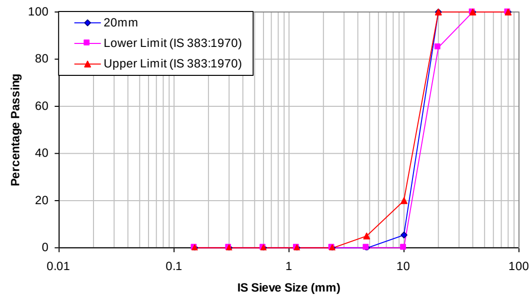


Fig. 3.1 Grading curve of 20 mm coarse aggregate

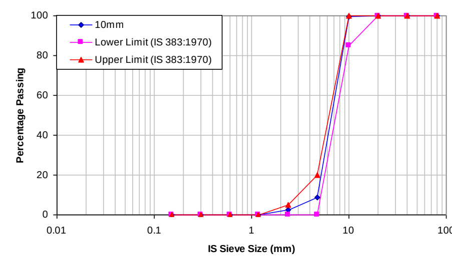


Fig. 3.2 Grading curve of 10 mm coarse aggregate

3.1.3. 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

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 9, September : 2023

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

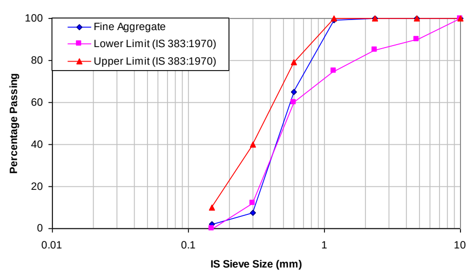


Fig. 3.3 Grading curve of fine aggregate

3.1.4. 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.

3.1.5 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.
Sieve Analysis of Copper Slag.

IS sieve size in mm	Copper slag Cumulative % retained
20.00	0.00
16.00	0.00
12.50	0.00
10.00	0.00
4.75	0.20
2.36	4.75
1.18	50.65
0.600	88.25
0.300	96.15
0.150	98.00
FM	**3.38**

Copper slag

properties	Average values
Water absorption	0.2% To 0.3%
Bulk density	2.24
Specific gravity	4
Fineness modulus	3.38

MECHANICAL PROPERTIES
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 universal testing machine (UTM). For this study

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 9, September : 2023

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 (mm^2 or in^2)

Compression testing machine (CTM)

FLEXURAL STRENGTH TEST

Another important strength property of concrete is the flexural strength of a concrete. Samples were tested for flexural strength at 28 days of curing. The testing machine apparatus used to measure the flexural strength of concrete in this experimental work is operated by hydraulics and has dial gauge displays for monitoring the rate of loading and the peak load on the sample at the time of failure.. The flexural strength tests were performed in general accordance with IS standard 516 "Methods of Tests for Strength of Concrete" Third point loading entails subjecting a beam sample to a loading condition which ensures that no shear stresses in the middle third of the sample between the two loading points. The sample experiences pure bending forces in this region. To perform this test, each beam was measured and marked at the points of loading to ensure even loading on the sample. Lines were drawn at 2.5, 17.5, 32.5, and 47.5 from one end, to help placement of the sample in the proper position. The loading heads were cleaned and lowered onto the starting position and all gauges were zeroed. A static load was applied with a constant rate until failure occurred. The peak load was obtained from the digital display and recorded. The flexural strength was then calculated using Equation:

fcr=Plbd2

Where,

fcr= Flexural Strength of Concrete, (kpa or psi)

P = Maximum load applied (KN or lb),

l= Length of the specimen between the supports in (mm or in),

b = Width of the beam (mm or in), and

d = Depth of the beam (mm or in)

TESTING OF FLEXURAL STRENGTH IN UTM

Split Tensile strength test`;

*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).

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 9, September : 2023


Split tensile set up in CTM


After applying load

DURABLE PROPERTIES SORPITIVITY
INTRODUCTION

Concrete is a porous material which interacts with the surrounding environment. The durability of mortar and concrete depends largely on the movement of water and gas enters and moves through it. The permeability is an indicator of concrete's ability to transport water more precisely with both mechanism that is controlling the uptake and transport of water and gaseous substances into cementitious material. Permeability is a measure of flow of water under pressure in a saturated porous medium while Sorptivity is materials ability to absorb and transmit water through it by capillary suction. Uptake of water by unsaturated, hardened concrete may be characterized by the sorptivity.

This is a simple parameter to determine and is increasingly being used as a measure of concrete resistance to exposure in aggressive environments. Sorptivity or capillary suction, is the transport of liquids in porous solids due to surface tension acting in capillaries and is a function of the viscosity, density and surface tension of the liquid and also the pore structure (radius, tortuosity and continuity of capillaries) of the porous solid. It is measured as the rate of uptake of water. Transport mechanisms act at the level of the capillary pores and depend on the fluid and the solid characteristics. The porous structure of concrete is intimately related with its permeability. A low water/cement ratio results in concrete structures which are less permeable because they are characterized by having small pores which are not interconnected.

TEST PROCEDURE

*The sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material.
*Water was used of the test fluid. The cylinders after casting were immersed in water for 28,56, and 90 days curing.
* The specimen size 100mm dia x 50 mm height after drying in oven at temperature of 100 + 10 °C were drowned with water level not more than 5 mm above.
*The specimen should be oven dried for 3 days and weight is measured.
*After 3days of oven dried specimen should be placed in a one side opened cover for `15 days


Specimen placed in cover

* After `15days the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non-absorbent coating. (layer will be on three sides only bottom should be opened)


Specimen with sealant

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 9, September : 2023

*The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a top pan balance weighting upto 0.1 mg.
*surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds.
*Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity.
*The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t)

Specimen placed in water

Weighing of specimen

The cumulative water absorption (per unit area of the inflow surface) increases as the square root of elapsed time (t) $I=S.t^{½}$
Therefore
$S=I/ t^{½}$
Where;
S= sorptivity in mm,
t= elapsed time in mint.
$I=\Delta w/Ad$
Δw= change in weight = W2-W1
W1 = Oven dry weight of cylinder in grams
W2 = Weight of cylinder after30 minutes capillary suction of water in grams.
A= surface area of the specimen through which water penetrated.
d= density of water

WATER ABSORPTION
INTRODUCTION

Concrete is a porous material which interacts with the surrounding environment. The durability of mortar and concrete depends largely on the movement of water and gas enters and moves through it. The permeability is an indicator of concrete's ability to transport water more precisely with both mechanism that is controlling the up-take and transport of water and gaseous substances into cementitious material. Permeability is a measure of flow of water under pressure in a saturated porous medium whileSorptivity is materials ability to absorb and transmit water through it by capillary suction. Uptake of water by unsaturated, hardened concrete may be characterised by the sorptivity. This is a simple parameter to determine and is increasingly being used as a measure of concrete resistance to exposure in aggressive environments. Sorptivity, or capillary suction, is the transport of liquids in porous solids due to surface tension acting in capillaries and is a function of the viscosity, density and surface tension of the liquid and also the pore structure (radius, tortuosity and continuity of capillaries) of the porous solid. It is measured as the rate of uptake of water. Transport mechanisms act at the level of the capillary pores and depend on the fluid and the solid characteristics. The porous structure of concrete is intimately related with its permeability. A low water/cement ratio results in concrete structures which are less permeable because they are characterized by having small pores which are not interconnected.

Water absorption test

*The 100mm dia x 50 mm height cylinder after casting were immersed in water for 90 days curing.
*These specimens were then oven dried for 24 hours at the temperature110°C until the mass became constant and again weighed.
*This weightwas noted as the dry weight (W1) of the cylinder.After that the specimen was kept in hot water at 85°c for 3.5 hours.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 9, September : 2023

*Then this weight was noted as the wet weight (W2) of the cylinder.

% water absorption = [(W2– W1) / W1] x 100

Where,

W1 = Oven dry weight of cylinder in grams

W2 = After 3.5 hours wet weight of cylinder in grams.

RAPID CHLORIDE PERMEABILITY TEST

Introduction

Reinforced concrete structures are exposed to harsh environments yet is often expected to last with little or no repair or maintenance for long periods of time (often 100 years or more). To do this, a durable structure needs to be produced. For reinforced concrete bridges, one of the major forms of environmental attack is chloride ingress, which leads to corrosion of the reinforcing steel and a subsequent reduction in the strength, serviceability and aesthetics of the structure. This may lead to early repair or premature replacement of the structure. A common method of preventing such deterioration is to prevent chlorides from penetrating the structure to the level of the reinforcing steel bar by using relatively impenetrable concrete. The ability of chloride ions to penetrate the concrete must then be known for design as well as quality control purposes. The penetration of the concrete by chloride ions, however, is a slow process. It cannot be determined directly in a time frame that would be useful as a quality control measure. Therefore, in order to assess chloride penetration, a test method that accelerates the process is needed, to allow the determination of diffusion values in a reasonable time.

Test Procedure (ASTM C 1202)

*Rapid chloride permeability test According to ASTM C1202 test, water-saturated, 50 mm thick, 100 mm thick diameter concrete specimen is subjected to applied DC voltage of 60 V for 6 hours.In one container 3.0% NaC1 solution and in the other container 0.3 M NaOH solution.

Fig RCPT APPARATUS

RCPT ratings as per ASTM C1202.

Charge Passing (Coulombs)	Charge Passing (Coulombs)
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very Low
<100	Negligible

Test Results and Discussion

The durability of fiber reinforced concrete that is resistance to chloride penetration is studied. Rapid chloride ion penetrability tests were for copper slag specimens, an electrical current recorded at 1 minute intervals over the 6 hour time, resulting in the total charge passed in coulombs is shown in Table and Table shows chloride permeability as per ASTM C 1202. The testing of specimen were done at 7 days, 14days, 28days and 56 days.. RCPT values for mix proportion

IV. RESULTS AND DISCUSSION

4.1 INTRODUCTION

In this Chapter, the test results are presented and discussed. The test results cover the strength properties of concrete using copper slag as partial and fully replacement of fine aggregate (0%, 20%, 30%, 40% .....and up to 100%). The strength and durable properties include compressive, splitting tensile and flexural strength, sorptivity, rapid chloride permeability, water absorption of concrete at different curing periods. The compressive strength values of concrete mixes were measured after 7, 28 and 56 days of curing. The splitting tensile and flexural strength values of

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 9, September : 2023

concrete mixes were measured after 28 days of curing and sorptivity and water absorption values taken at days of curing and RCPT values are taken at 28 days .

4.2 Mechanical properties of copper slag based concrete

This section discusses the mechanical properties of both CC (CWR_0) and CWR based concrete mixes at different curing periods.

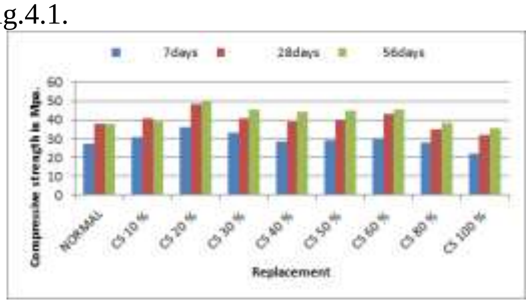
4.2.1. Compressive strength

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

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.



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.

4.2.2. 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

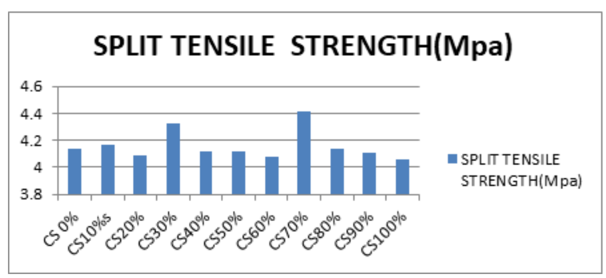


Fig. 4.2 Splitting tensile strength of mixes for 28 days

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

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 9, September : 2023

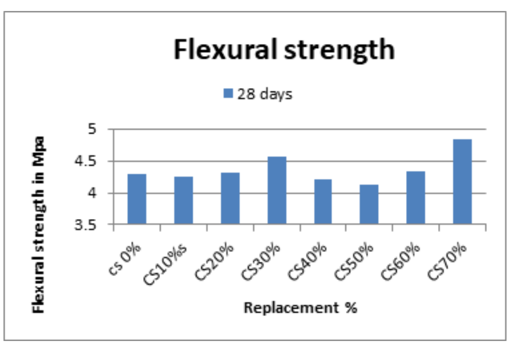
values are found to be almost equal to the CC. The STS values of the concrete mixes CS_30 and CWR_70 are comparable to that of M 25 grade of CC at all ages. The further increase in replacement of CS decreased the STS values significantly as in the case of the concrete mixes CS_20 and CS_30. Hence, it can be recommended to use CS at 70% partial replacement of fine aggregate in order to attain the desired values of CC.

4.2.3. Flexural strength

Table 4.3 shows the splitting tensile strength (STS) values of concrete with partial replacement of CWR.

Table 4.3 Flexural strength of concrete

MIX PROPORTIONS	FLEXTURE STRENGTH(Mpa)
CS 0%	4.24
CS10%s	4.26
CS20%	4.32
CS30%	4.56
CS40%	4.22
CS50%	4.12
CS60%	4.33
CS70%	4.84
CS80%	4.41
CS90%	4.27
CS100%	4.11



It is observed that, the flexural strength of concrete at 28 days is higher than design mix (Without replacement) for 20% replacement of fine aggregate by Copper slag, the flexural strength of concrete is increased by 14%. This also indicates flexural strength is more for all percentage replacements than design mix.

It is observed that the replacement of the copper slag partially at 30% and 70 % the flexural strength values are more when compared with the remaining values ,and at te replacement of 70% of copper slag we get the maximum flexural strength when compared with the all mix replacements.

DURABLE PROPERTIES

4.2.4 RAPID CHLORIDE PERMEABLITY TEST

Table shows that results of this experiment In this experiment the chloride passes through the concrete sample which taken at the curing periods 28 days , this passing chloride shows that the permeability of the concrete ,the charge passed through coloumbs values are taken from the equipment display, and this values are compared with the standard values which are mentioned by ASTM C1202 .

As observed the highest charge passed through the sample which is replacement with copper slag 50% (3645) ,and the lowest value passed through the sample which is replaced by the copper slag with 30%(2011).finally all values are shown that moderate values when compared with the table according to ASTM C1202.

Table 4.4 RCPT VALUES OF CONCRETE

Specimen Designation	Charge Passed Through In Coloumbs (C)	Chloride Permeability Results As Per ASTM C 1202
CS10%s	2908	MODERATE
CS20%	2212	MODERATE
CS30%	2011	MODERATE
CS40%	2564	MODERATE
CS50%	3645	MODERATE
CS60%	3541	MODERATE
CS70%	2254	MODERATE
CS80%	3362	MODERATE
CS90%	3331	MODERATE
CS100%	2145	MODERATE

4.2.5 SORPTIVITY

Table shows that the results of the sorptivity experiment, as the results the values of sorptivity it is reported that the values of sorptivity of the concrete is highest at the replacement of the copper slag 90% and the water absorption rate is also observed as the more , and lowest value reported at the replacement of copper slag 30%.

The values of sorptivity and water absorption is same as normal conventional concrete at the replacement levels of copper slag are CS 10% and CS 30%

Specimen Designation	Sorptivity Value (x 10^{-6}) mm/ $min^{0.5}$	Absorption Rate I = S.t ½ mm
CS 0%	4.50	101.62
CS10%s	4.60	100.14
CS20%	5.36	111.23
CS30%	4.55	104.2
CS40%	6.28	125.6
CS50%	6.94	134.01
CS60%	8.23	141.03
CS70%	7.12	139.2
CS80%	8.66	154.17
CS90%	9.23	174.23
CS100%	7.48	152.9

Table 4.5 sorptivity values

V. CONCLUSIONS

1) Greatest Compressive strength of concrete for a substitution of fine total by 20% of copper slag expanded by 34% at 7 days and expanded by 29% at 28 days. Comparable expansion is seen at 56 days strength.
2) Replacement of copper slag up to 80% will expand the strenth of design mix ,after that 80% substitution the strength began to lessen. The strength at 100 % substitution is decreased by 7% at 28 days.
3) It is watched that, the flexural strength of concrete at 28 days is higher than configuration design mix (Without substitution) for 20% substitution of fine total by Copper slag, the flexural strength of concrete is expanded by 14%. This likewise shows flexural strength is more for all rate substitutions than configuration design mix.
4) Compressive strength and Flexural strength was expanded because of the high sturdiness property of Copper slag.
5) Chloride penetrability of the solid saw as moderate.

REFERENCES

[1] Al-Jabri K.S., Taha R.A., Al-Hashmi A., Al Harthy A.S.,"Effect of copper slag and cement by-pass dust addition on mechanical properties of concrete", *Construction and Building Materials*,*2006*, *Volume no. 20*, pp.322–331.

[2] Alp, H. Deveci, H. Sungun, "Utilization of flotation wastes of copper slag as raw material in cement production", *Journal of Hazardous Materials*,2008, *Volume no. 159*, pp.390–395.

[3] Brindha D., Baskaran.T, Nagan.S, "Assessment of Corrosion and Durability Characteristics of Copper Slag Admixed Concrete", *International journal of civil and structural engineering,2010, Volume 1, No 2*, pp.192 – 211

[4] Khalifa S. Al-Jabri , Makoto Hisada , Abdullah H. Al-Saidy , S.K. Al-Oraimi, "Performance of high strength concrete made with copper slag as a fine aggregate", *Construction and Building Materials, 2009 , Volume no. 23*, pp.2132–2140.

[5] Khalifa S. Al-Jabri, Abdullah H. Al-Saidy, Ramzi Taha, "Effect of copper slag as a fine aggregate on the properties of cement mortars and concrete", *Construction and Building Materials, 2011*, Volume no.25, pp.933–938.

[6] M. Najimi, J. Sobhani, A.R. Pourkhorshidi,, "Durability of copper slag contained concrete exposed to sulfate attack", *Construction and Building Materials, 2011, Volume no.25,* pp. 1895–1905

[7] Meenakshi Sudarvizhi. S, Ilangovan. R, "Performance of Copper slag and ferrous slag as partial replacement of sand in Concrete", *International journal of civil and structural engineering, 2011*, *Volume 1*, pp.918 – 927

[8] Wei Wua, Weide Zhang a, Guowei Maa,, "Optimum content of copper slag as a fine aggregate in high strength concrete", *Materials and Design, 2010, Volume no. 31*, pp. 2878–2883

[9] Thematic focus: Ecosystem management, Environmental governance, Resource efficiency. 26 Oct 2015. Available from: http://na.unep.net/geas/getUNEPPageWithArticleIDScript.php?article_id=110

[10] Al-Jabri KS, Al-Saidy AH, Taha R. Effect of copper slag as a fine aggregate on the properties of cement mortars and concrete. Construction and Building Materials. 2011; 25(2): 933-8.

[11] Madheswaran CK, Ambily PS, Dattatreya JK, Rajamane NP. Studies on use of Copper Slag as Replacement Material for River Sand in Building Constructions. Journal of the Institution of Engineers (India): Series A. 2014; 95(3):169-77.

[12] Khanzadi M, Behnood A. Mechanical properties of high-strength concrete incorporating copper slag as coarse aggregate. Construction and Building Materials. 2009; 23(6):2183-8.

[13] Pacheco-Torgal F, Jaalai S. Compressive strength and durability properties of ceramic wastes based concrete. Materials and Structures. 2011; 44(1):155-67.

[14] Vanitha S, Natarajan V, Praba M. Utilisation of waste plastics as a partial replacement of coarse aggregate in concrete blocks. Indian Journal of Science and Technology. 2015; 8(12):1-6.

[15] IS 12269:2013. Indian Standard Ordinary Portland Cement. 53 Grade-Specifications. Bureau of Indian Standards. New Delhi, India; Bureau of Indian Standards; 2013.

[16] IS 10262:2009. Indian Standard Concrete Mix Proportioning - Guidelines. Bureau of Indian Standards. New Delhi, India: Bureau of Indian Standards; 2009.