International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 Issue: XII Month of publication: December 2017

DOI:

An Experimental Investigation on the Mechanical and Durability Properties of M_{30} Concrete with Partial Replacement of Coarse Aggregate by Steel Slag and Fine Aggregate by Copper Slag

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Abstract: ***The waste products that are produced from industries cause harmful effects to the environment if they are not properly utilized. About 12 million tones of steel slag and about 24.6 million tons of copper slag are generated annually worldwide. In order to utilize these waste products effectively, are attempt in made to study the mechanical and durability properties of M_{30} concrete using steel slag produced by local steel plant as CA and copper slag as FA. By varying the proportions of steel slag and copper slag replacements from 10% to 40% at an increment of 10%,Concrete specimens were prepared and tested for mechanical properties viz compressive strength and split tensile strength. The durability tests namely water permeability test and (RCPT) Rapid Chloride permeability tests were conducted. The results are compared with conventional OPC concrete. It is observed that both the steel slag and copper slag enhance the mechanical and durability properties. The waste products that are produced from industries cause harmful effects to the environment if they are not properly utilized. About 12 million tones of steel slag and about 24.6 million tons of copper slag are generated annually worldwide. In order to utilize these waste products effectively, are attempt in made to study the mechanical and durability properties of M_{30} concrete using steel slag produced by local steel plant as CA and copper slag as FA. By varying the proportions of steel slag and copper slag replacements from 10% to 40% at an increment of 10%,Concrete specimens were prepared and tested for mechanical properties viz compressive strength and split tensile strength. The durability tests namely water permeability test and (RCPT) Rapid Chloride permeability tests were conducted. The results are compared with conventional OPC concrete. It is observed that both the steel slag and copper slag enhance the mechanical and durability properties.***

Key words: Steel slag, Copper slag, Mix design, Mechanical Properties, Rapid chloride permeability test, water permeability test.

I. INTRODUCTION

It is a known fact that the natural materials (raw materials) used for the production of cement are depleting at a greater pace worldwide and there is no replenishment for these material. On the other hand many industries are generating waste material whose safe, effective and economical use is yet to be explored fully. Sustainable development of construction industry needs the usage of non conventional material, innovative and recycled material (Aggarwal and Siddique- 2014 ;) in order to compensate the depleting natural material and at the same time to conserve environment. The production of steel slag in India is 12 million tones per year(V.subathra Devi & B.K.Granavel-2014) and the production of copper slag is 24.6 million tones per year (KhalifaS. Al.Jabri et al-2011). In order to add value to these materials and for sustainability, there is a need to search for alternative uses of these materials, which not only consume these wastes at larger scale but also enhance the value of these waste products.

It is a proven fact that concrete has much scope for the usage of these waste materials as it is the largely consumed material after water. In the present study an attempt is made to use these by-products/waste materials as partial replacement to natural aggregate in concrete and evaluated the mechanical and durability properties of concrete.

II. EXPERIMENTAL PROGRAM

A. Materials

1) Cement

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887
Volume 5 Issue XII December 2017- Available at www.ijraset.com

Cement is the most important material in concrete and it acts as a binding material. The cement of 53 gradeOPC manufacturedby Zuari Cement Company confirming to IS 12269-1987 is used in the present investigation.

TABLE 2.1
PROPERTIES OF CEMENT

S.No	Property	Test results
1	Normalconsistency	29%
2	Specific gravity	3.15
3	Initial settingtime	30minutes
4	Finalsettingtime	600minutes

2) *Fine aggregate*

In this investigation, natural sand is used as fine aggregate. The specific gravity of sand is found to be 2.62. Sand was obtained from Cheyyeru River near Nandalur in Kadapa district.

TABLE2.2
PROPERTIES OF FINEAGGREGATE

S.No	Paticulars	Results
1	Type	Normal sand
2	Specific gravity	2.62
3	Grading size	4.75mm -0.075mm
4	Water absorption	1%
5	Fineness modulus	2.28
6	Bulk density	1378.2 Kg/m3

3) *Coarse Aggregate:* In the present investigation, crushed granite aggregate of 20mm size is used. The specific gravity of coarse aggregate is 2.64.

TABLE 2.3
PHYSICALPROPERTIES OF COARSEAGGREGATE

S.No	Paticulars	Results
1	Type	Crushed stone
2	Specific gravity	2.64
3	Maximum size	20 mm
4	Water absorption	0.5%
5	Fineness modulus	4.30
6	Bulk density	1388 Kg/m3

4) *Water:* Water is used for mixing and curing of concrete. In the present investigation, tap water available in the campus was used for both mixing and curing of concrete.

TABLE 2. 4
PHYSICALPROPERTIES OFWATER

S.No	Property	Value
1	pH	7.1
2	Taste	Agreeable
3	Appearance	Clear
4	Turbidity(NTunits)	1.75

5) *Steel Slag:* In the present investigation, crushed steel slag aggregate of 20mm size was used. The specific gravity of steel slag is 3.45. The chemical composition of steel slag is furnished in table no.2.5.

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Fig.2.1:Steel slag

TABLE 2.5
CHEMICAL COMPOSITION OF STEEL SLAG

Elements	Composition
Carbon	1.40%
Oxygen	54.05%
Sodium	0.58%
Aluminium	4.49%
Silicon	18.28%
Potassium	0.33%
Calcium	1.46%
Titanium	0.49%
Chromium	0.32%
Manganese	3,67%
Zinc	0.32%
Iron	14.52%

*6) Copper Slag:*The copper slag used is the present investigation is procured from Vivekananda chemicals, Hyderabad. The slag is a black glassy and granular in nature and has a similar particle size range of sand which indicates that it could be tried as replacement with sand in cementations mixture. The other main advantage of using Copper slag (a waste material) is to reduce the cost of construction. (Al-Jabri et al 2009).copper slag has a number of favorable mechanical properties for aggregate use such as excellent soundness characteristics, good abrasion resistance and good stability conditions (Gorai 2002). In the present investigation, copper slag aggregate sieved through 4.75 to 150 micronsieves and conforming to zone II (of sand) size was used. The specific gravity of copper slag is 2.82.

Fig. 2.2: Copper slag

TABLE 2.6
CHEMICAL COMPOSITION OF COPPER SLAG

Elements	Composition
Silicon oxide (SiO_2)	97.01
Aluminum oxide (Al_2O_3)	0.095
Iron oxide (Fe_2O_3)	1.05
Calcium oxide (CaO)	1.064
Magnesium oxide (MgO)	0.118
Sulfur trioxide (SO_3)	0.008
Potassium oxide (K_2O)	0.028
Sodium oxide (Na_2O)	0.118
Titanium oxide (TiO_2)	0.120
Manganese oxide (Mn_2O_3)	0.002
Copper oxide (CuO)	0.183
SulphideSulphur	0.082

B. Concrete Mix design

Concrete mix design can be defined as the process of selecting suitable ingredients of concrete and determining their relative proportions with the objectives of producing concrete of certain minimum strength and durability as economically as possible. The concrete mix was designed using the guide lines given in IS 10262 -2009 and IS 456-2000 codes. The details of mix proportions (1:2:3.26) and the proportions of various ingredients of concrete are given below.

TABLE 2.7
QUANTITIES OF MATERIALS

S.No.	Material	As per mix design Kg/m^3
1	Cement	352
2	Fine aggregate	710
3	Coarse aggregate	1167
4	Water	176

Control concrete mixture of M30was designated as A1. The other concrete mix proportions by replacing CA with steel slag at 10%,20%,30% and 40% were designated as A1, A2, A3, A4 and A5 and the concrete mixes made by replacing FA with copper Slag 10%, 20%, 30%, 40% were designated as A1,A6,A7,A8 AND A9. Mix proportions of A1 to A9 concrete mixtures are given in table 2.8

TABLE 2.8
MIXTURE PROPORTIONS

Material	A1	A2	A3	A4	A5	A6	A7	A8	A9
Cement, Kg/m^3	352	352	352	352	352	352	352	352	352
Steel slag %	0	10	20	30	40	0	0	0	0
Steel slag, Kg/m^3	0	152.51	305.02	457.53	610.04	0	0	0	0
Coarse aggregate, Kg/m^3	1167	1034.42	919.4	804.5	689.61	0	0	0	0
Copper slag %	0	0	0	0	0	10	20	30	40
Copper slag, Kg/m^3	0	0	0	0	0	86.70	173.40	260.10	346.80
Fine aggregate, Kg/m^3	710	0	0	0	0	617.7	567.89	496.9	425.91
Water Kg/m^3	176	176	176	176	176	176	176	176	176
W/binder	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

C. Testing procedures

1) *Compressive Strength Test:* The compressive strength of concrete(150 mm × 150 mm × 150 mm) was tested using compression testing machine according to IS 516-1959.The concrete cubes were tested at7days, 14 days and 28 days and 60 days curing period. The cube compressive strength is calculated. The ratio of failure load to the area of cross section.

If f_c is the cube compressive strength,

Then $f_c = \frac{P}{A}$ N/mm2,

Where P is an ultimate load in Newtons.

A is a cross sectional area of cube in mm^2.

2) *Split Tensile Strength Test:* Split tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. Spilt

Tensile strength of concrete found by the procedure prescribed by IS 5816 – 1999. Specimens of 150mm diameter × 300mm height were used for this test. The specimens were tested for 7, 14, 28 and 60days strength. The cylindrical specimen was placed in horizontal direction on the testing machine. The load was applied uniformly at a constant rate of 1.5 N/mm2until the failure by splitting along the vertical axis took place. Loads at which specimen failed were recorded and tabulated. Then split tensile strength was calculated. The following relation is Used to find out the spilt tensile strength of cylinder, $Ft = \frac{2P}{\Pi DL}$

Where Ft is split tensile strength

P= Ultimate load in Newton.

L = Length of the cylinder in mm.

D = Diameter of the cylinder in mm.

3) *Rapid Chloride ion permeability test:* In the chloride permeability test, a water-saturated, 50 mm thick, 100 mm diameter concrete specimen is subjected to a 60v applied DC voltage for 6 hours using the RCPT apparatus. In one reservoir 3.0% NaCl solution and in the other reservoir is a 0.3 M NaOH solution was filled. The test was conducted as per the procedure prescribed in ASTMC 1202. The total charge passed is determined using the formula

$$I=900(I_0+2(I_{30}+I_{60}+\text{-----}I_{330})+I_{360})$$

4) *Water permeability test:* In the present investigation the water permeability of concrete was tested by using depth of penetration test. The

Permeability is measured by using Darcy's law.

$$K=\frac{d2v}{2ht}$$

d= depth of penetration in (m)

v= volume of water occupied by pores

h= hydraulic head in m

t= time in seconds

$v=\frac{1000m}{Ad}$

m=gain in mass (grams)

A= c/s area of sample (mm^2)

d= depth of penetration in mm

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

A. Compressive Strength of concrete with steel slag

TABLE 3.1
COMPRESSIVE STRENGTH TEST RESULTS FOR CONCRETE WITH STEEL SLAG

Mix Designation	Proportions of coarse aggregate	Compressive strength N/mm^2		
		7-days	14-days	28-days
A1	100 % CA	22.93	34.0	37.55

A2	90 % CA + 10% steel slag	24.323	35.11	39.20
A3	80% CA + 20 % steel slag	27.52	36.26	42.25
A4	70% CA + 30% steel slag	26.84	27.74	36.70
A5	60% CA + 40 % steel slag	25.37	26.69	31.77

At 7 days curing age, it was observed that the compressive strength showed an increase as the steel slag content increased up to20%.

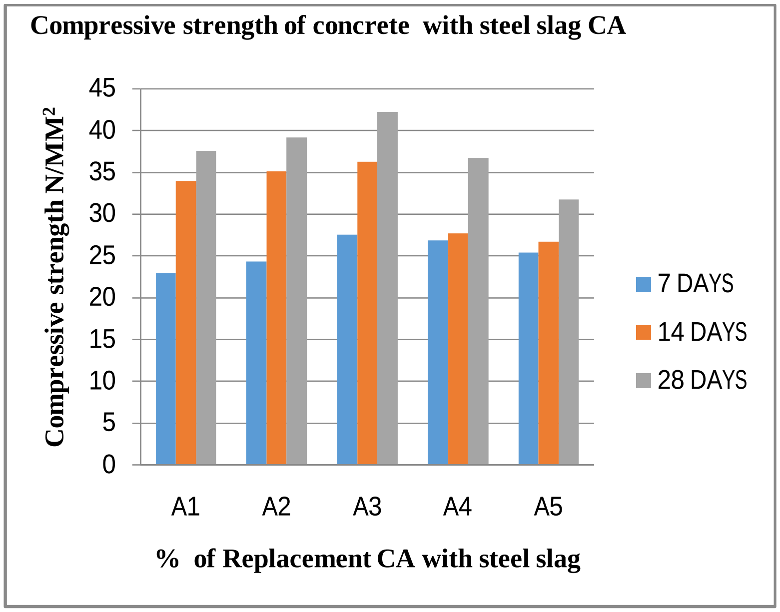


Fig 3.1:Compressive strength Vs percentage of CA and steel slag

At 7 days ,it is observed that the Compressive strength of M30 grade concrete with steel slag coarse aggregate increased with increase in percentage of steel slag. The increase in compressive strength is 6%,20%,17% and 10.6% more than the conventional concrete. The M30 concrete with 20% steel slag has yield highest compressive strength at 7 days. At 14 days ,it is observed that the compressive strength of M30 grade concrete with steel slag coarse aggregate increased with increase in percentage of steel slag. The increase in compressive strength is 3%,6%,18.4% and 21.5% more than the conventional concrete. The M30 Concrete with 20% steel slag has yield highest compressive strength at 14 days. At 28 days ,it is observed that the compressive strength of M30 grade concrete with steel slag coarse aggregate increased with increase in percentage of steel slag. The increase in compressive strength is 4.3%,12.5%,22.6% and 15.3% more than the conventional concrete. The M30 concrete with 20% steel slag has yield highest compressive strength at 28 days.

B. Compressive Strength of concrete with copper slag

TABLE 3.2

COMPRESSIVE STRENGTH TEST RESULTS FOR CONCRETE WITH COPPER SLAG

Mix Designation	Proportions of fine aggregate	Compressive strength N/mm^2		
		7-days	14-days	28-days
A1	100 % FA	22.93	34.0	37.55
A6	90% FA + 10% copper slag	27.99	35.45	38.67
A7	80% FA+ 20 % copper slag	29.00	36.12	41.34
A8	70% FA+ 30% copper slag	31.24	38.43	43.90
A9	60% FA + 40 % copper slag	26.75	31.73	36.12

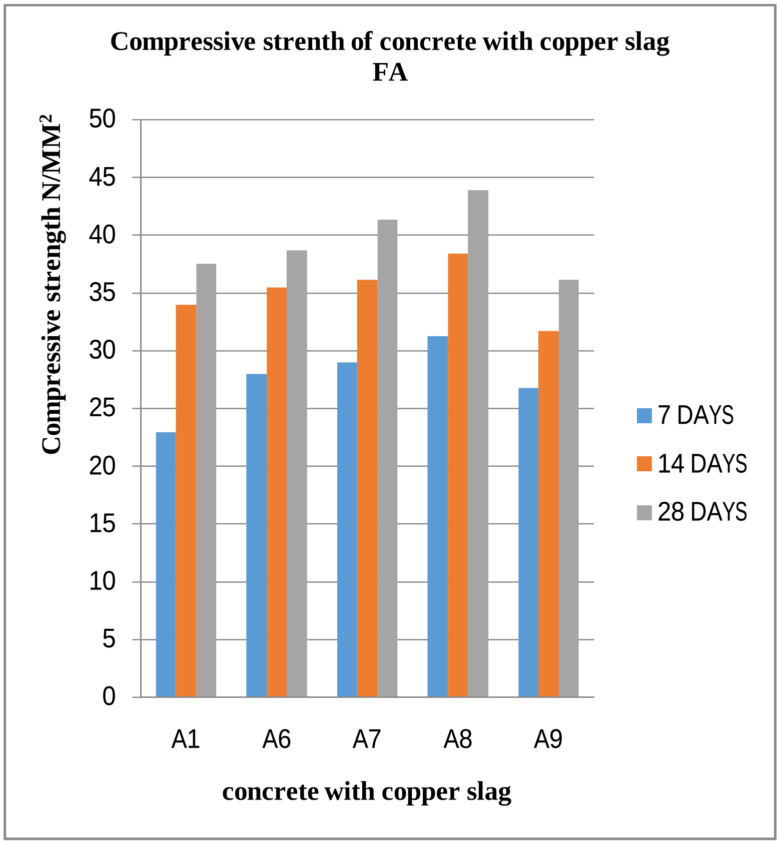


Fig 3.2:Compressive strength Vs percentage of F.S and copper slag

At 7 days ,it is observed that the Compressive strength of M30 grade concrete with copper slag fine aggregate increased with increase in percentage of copper slag. The increase in compressive strength is 22%,26.4%,36.2% and 16.6% more than the conventional concrete. The M30 concrete with 30% copper slag has yield highest compressive strength at 7 days. At 14 days ,it is observed that the compressive strength of M30 grade concrete with copper slag fine aggregate increased with increase in percentage of copper slag. The increase in compressive strength is 4.2%,6.2%,13% and 6.6% more than the conventional concrete. TheM30 Concrete with 30% copper slag has yield highest compressive strength at 14 days. At 28 days, it is observed that the compressive strength of M30 grade concrete with copper slag fine aggregate increased with increase in percentage of copper slag. The increase in compressive strength is 2.9%,10%,16.9% and 3.8% more than the conventional concrete. The M30 concrete with 30% copper slag has yield highest compressive strength at 28 days.

C. Split Tensile Strength of concrete with steel slag

TABLE 3.3
SPLIT TENSILE STRENGTH TEST RESULTS FOR STEEL SLAG

Mix Designation	Percentages of natural CA and Steel slag	Split Tensile Strength N/mm^2		
		7-days	14-days	28-days
A1	100% CA	2.16	3.11	3.42
A2	90 % CA+10 % steel slag	2.43	3.69	4.18
A3	80 % CA+20 % steel slag	2.55	3.90	4.32
A4	70 % CA+30 % steel slag	2.50	3.20	3.64
A5	60 % CA+40 % steel slag	2.44	2.84	3.07

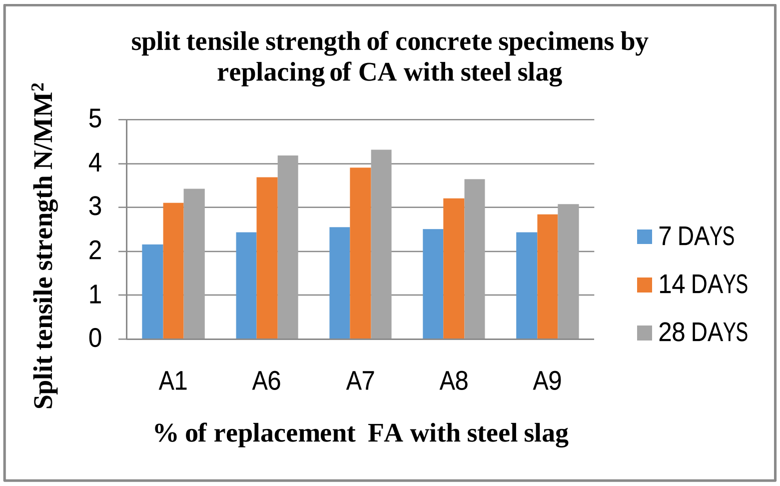


Fig 3.3:Split tensile strength Vs percentage of CA and steel slag

At 7 days ,itis observed that the split tensile strength of M30 grade concrete with steel slag coarse aggregate increased with increase in percentage of steel slag. The increase in splittensile strength is 12.5%,18%,15.7% and 12.7% more than the conventional concrete. The M30 concrete with 20% steel slag has yield highest split tensile strength at 7 days. At 14 days, it is observed that the split tensile strength of M30 grade concrete with steel slag coarse aggregate increased with increase in percentage of steel slag. The increase in split tensile strength is 18.6%,25.4%,2.8% and 8.6% more than the conventional concrete. The M30 Concrete with 20% steel slag has yield highest split tensile strength at 14 days. At 28 days ,it is observed that the split strength of M30 grade concrete with steel slag coarse aggregate increased with increase in percentage of steel slag. The increase in split tensile strength is 22.2%,26.3%,6.4% and 10.2% more than the conventional concrete. The M30 concrete with 20% steel slag has yield highest split tensile strength at 28 days.

D. Split Tensile Strength of concrete with copper slag

TABLE 3.4

SPLIT TENSILE STRENGTH TEST RESULTS FOR USING COPPER SLAG

Mix Designation	Percentages of natural FA and copper slag	Split Tensile Strength N/mm^2		
		7-days	14-days	28-days
A1	100% FA	2.16	3.11	3.42
A6	90% FA+10% copper slag	2.41	3.25	3.67
A7	80 % FA+20 % copper slag	2.64	3.72	4.10
A8	70% FA+30 % copper slag	2.80	3.98	4.42
A9	60 % FA+40% copper slag	2.43	3.12	3.51

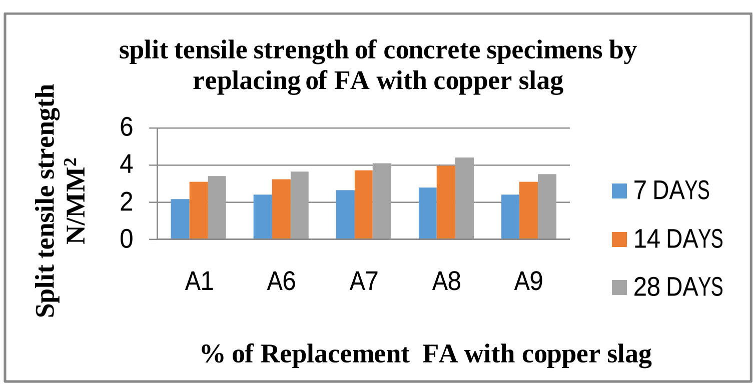


Fig3.4: Split tensile strength Vs percentage of FA and CS

At 7 days ,it is observed that the split strength of M30 grade concrete with copper slag fine aggregate increased with increase in percentage of copper slag. The increase in split tensile strength is 11.5%,22.2%,29.6% and 12.5% more than the conventional concrete. The M30 concrete with 30% copper slag has yield highest split tensile strength at 7 days. At 14 days ,it is observed that the split tensile strength of M30 grade concrete with copper slag fine aggregate increased with increase in percentage of copperslag. The increase in split tensile strength is 4.5%,19.6%,27.9% and 0.3% more than the conventional concrete. The M30 Concrete with 30% copper slag has yield highest split tensile strength at 14 days. At 28 days ,it is observed that the split tensile strength of M30 grade concrete with copper slag fine aggregate increased with increase in percentage of copper slag. The increase in split tensile strength is 7.3%,19.8%,29.2% and 2.6% more than the conventional concrete. The M30 concrete with 30% copper slag has yield highest split tensile strength at 28 days.

E. Rapid chloride permeability test:

The Rapid chloride permeability test was conducted on M30 grade concrete mixes replacing CA by steel slag at 10%, 20%, 30% and 40%. The results of rapid chloride permeability test of A1, A2, A3, A4 and A5 concrete mixtures tested at 28 days and 60 days are represented in table 3.5.

TABLE 3.5
CHLORIDE ION PERMEABILITY RATING FOR STEEL SLAG

Designation of mix	Proportion of coarse aggregate	Charge passed in columns	
		28 days	60 days
A1	Conventional mix	1150.50	1030.50
A2	90% CA+10% steel slag	1174.60	1080.90
A3	80 % CA+20 % steel slag	1258.20	1145.40
A4	70% CA+30 % steel slag	1390.50	1250.60
A5	60 % CA+40% steel slag	1480.70	1348.30

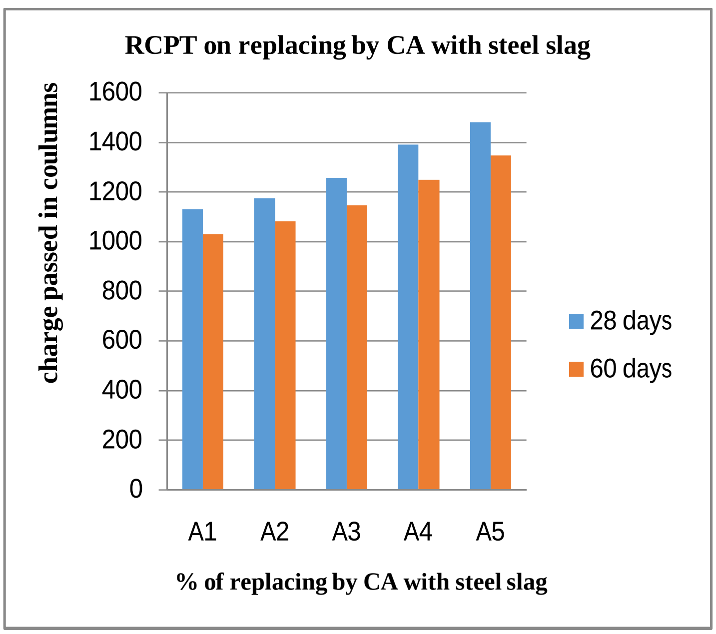


Fig. 3.5: chloride Vs percentage of CA and Steel slag penetration

The above figure shows the chloride diffusion in terms of the total charge passed through the specimen. it is observed that the total charge passed through the concrete specimen with replacement of coarse aggregate with steel slag increased with increase in percentage of slag .The chloride permeability decrease with age. The total charge passed through the M30 Concrete specimen with steel slag coarse aggregate up to 40% indicate that the concrete has low chloride ion permeability.

F. Rapid chloride permeability test for copper slag :

The Rapid chloride penetration test of M30 grade concrete mixes replacing FA by copper slag at 10%, 20%, 30% and 40%. The results of rapid chloride permeability test of A1, A6, A7, A8 and A9 concrete mixtures tested at 28 days and 60 days are represented in table 3.6.

TABLE 3.6
CHLORIDE ION PERMEABILITY RATING FOR COPPER SLAG

Mix designation	Proportion of fine aggregate	Charge passed in columns	
		28 days	60 days
A1	Conventional mix	1150.5	1045.60
A6	90% FA+10% copper slag	1150.0	1060.30
A7	80 % FA+20 % copper slag	1224.3	1020.40
A8	70% FA+30 % copper slag	1405.60	1142.40
A9	60 % FA+40% copper slag	1586.30	1244.50

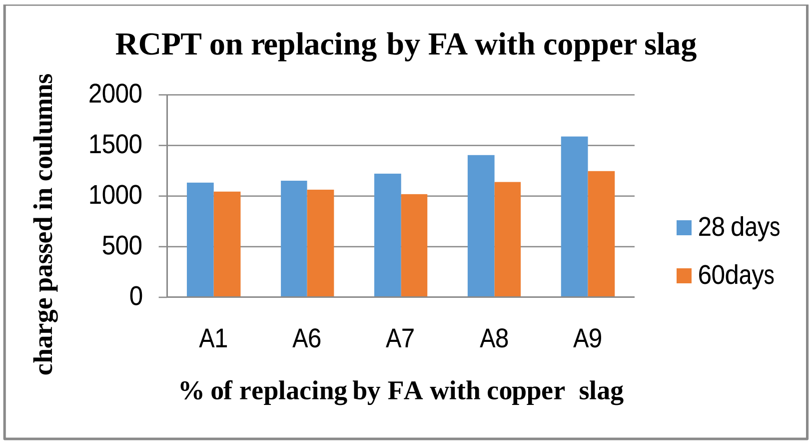


Fig. 3.6: chloride penetration Vs percentage of FA and copper slag

The above figure shows the chloride diffusion in terms of the total charge passed through the specimen. It is observed that the total charge passed through the concrete specimen with replacement of fine aggregate with copper slag increased with increase in percentage of slag .The chloride permeability decrease with age. The total charge passed through the M30 Concrete specimen with copper slag fine aggregate up to 40% indicate that the concrete has low chloride ion permeability.

G. Water penetration of concrete with steel slag as coarse aggregate

The test results for 60 days of water penetration with various percentages replacement of Coarse aggregate with steel slag are presented in table 3.7

TABLE 3.7
WATER PENETRATION TEST RESULTS OF CONCRETE WITH STEEL SLAG AS CA.

Mix no.	Proportion of coarse aggregate	Depth of water penetration in mm	Weigth of water penetrated in grms	Coefficient of Water Permeability,m/ sec for 60 days
A1	Conventional mix	21	50	9.02×10^{-13}
A2	90% CA+10% steel slag	13.1	50	5.91×10^{-13}
A3	80 % CA+20 % steel slag	15.3	50	6.90×10^{-13}
A4	70% CA+30 % steel slag	14.6	50	6.59×10^{-13}
A5	60 % CA+40% steel slag	15.8	50	7.13×10^{-13}

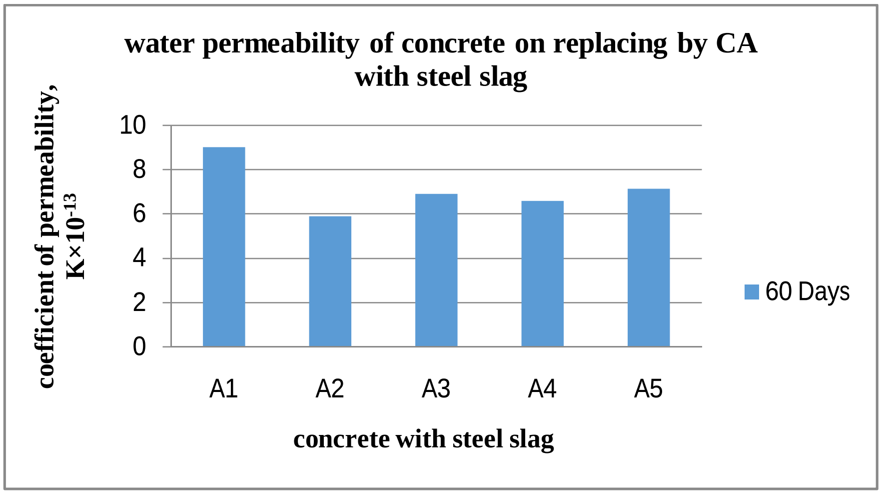


Fig. 3.7:water penetration Vs percentage of CA and SS

H. Water penetration of concrete with copper slag as fine aggregate:

The test results for 60 days of water penetration with various percentages replacement of fine aggregate with copper slag are presented in table 3.8.

TABLE 3.8

Water penetration test results of concrete with copper slag as fa.

Mix no.	Proportion of fine aggregate	Depth of water penetration in mm	Weigth of water penetrated in grms	Coefficient of Water Permeability
				60 days
A1	Conventional mix	21	50	9.02×10^{-13}
A6	90% FA+10% copper slag	15.7	50	7.08×10^{-13}
A7	80 % FA+20 % copper slag	17.2	50	7.72×10^{-13}
A8	70% FA+30 % copper slag	17.5	50	7.89×10^{-13}
A9	60 % FA+40% copper slag	18.5	50	8.35×10^{-13}

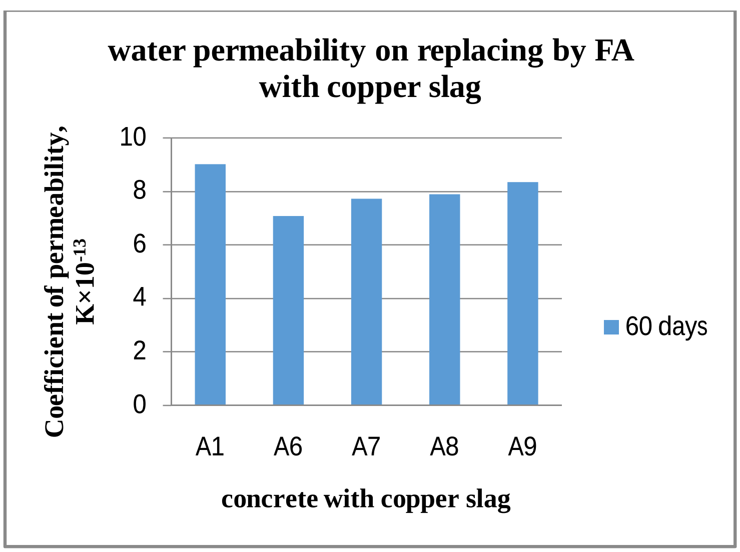


Fig. 3.8:water penetration Vs percentage of FA and CS

IV. CONCLUSIONS

A. The compressive strength of M_{30} concrete increases with increase in the replacement of CA with steel slag CA. Maximum compressive strength is obtained for 20% replacement of CA. The increase in compressive strength at 28 days is about 15% when compared to the concrete with natural CA.

B. The compressive strength of M_{30} concrete increases with increase in the replacement of FA with copper slag FA. Maximum compressive strength is obtained for 30% replacement of FA. The increase in compressive strength at 28 days is about 16.9% when compared to the concrete with natural FA.

C. The split tensile strength of M_{30} concrete with steel slag as CA increases with increase in percentage of slag aggregate up to 20% of replacement. The maximum tensile strength obtained is about 26% when compared to conventional concrete.

D. The split tensile strength of M_{30} concrete with copper slag as FA increases with increase in percentage of slag aggregate up to 30% of replacement. The maximum tensile strength obtained is about 29% when compared to conventional concrete.

E. The chloride resistance of M_{30} concrete slightly decreases with increase in replacement of CA by steel slag aggregate. There is an increase in chloride resistance with age. i.e the concrete with 20% steel slag aggregate showed highest resistance at 60 days.

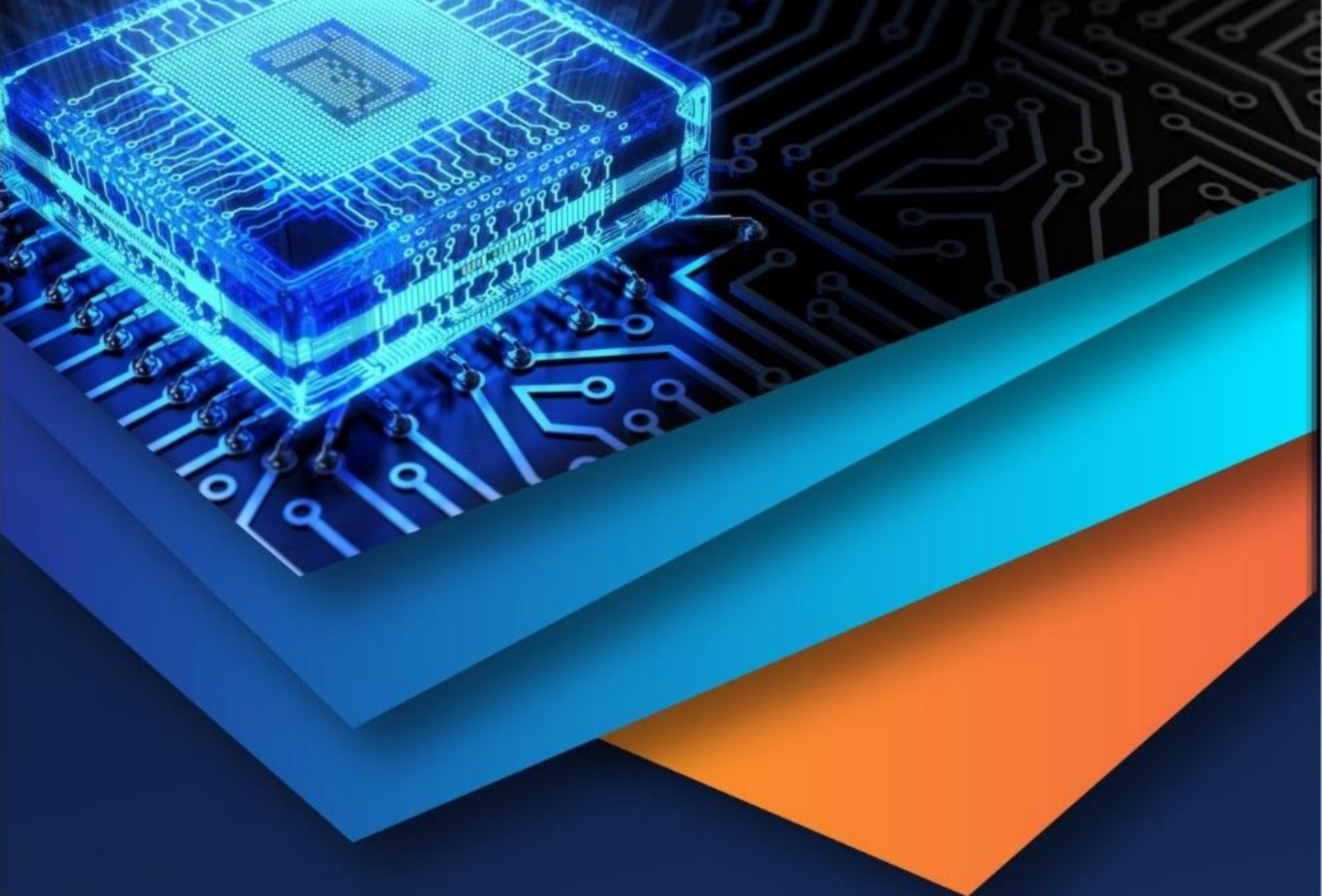
F. The chloride permeability of M_{30} concrete slightly increases with increase in replacement of FA with copper slag aggregate. There is reduction in chloride permeability of slag concrete with age. The lowest passage of charge is obtained for the concrete with 20% of copper slag fine aggregate.

G. The water permeability of concrete decreases with replacement of steel slag as coarse aggregate. The concrete with 30% of steel slag showed least water permeability when compared to conventional concrete.

H. The water permeability of concrete increases with increase in replacement of FA with copper slag aggregate. The concrete with 30% of copper slag showed least water permeability when compared to conventional concrete the percentages of copper slag is less water absorption.

REFERENCES

[1] Aggarwal, Y., Siddique, R., 2014. Microstructure and properties of concrete using bottom ash and waste foundry sand as partial replacement of fine aggregates. Constr. Build. Mater. 54, 210–223.
[2] V.Subathradevi&B.K.Granavel –(2014) Steel slag as a partial replacement of coarse aggregate in concrete,volume 97-2014
[3] Khalifa S. Al-Jabri, Abdullah H. Al-Saidy, RamziTaha(2011), Effect of copper slag as a fine aggregate on the properties of cement mortars and concrete , Construction and Building Materials ,25 pp.933–938.
[4] Jin Liu,Dongmin Wang-(2017).,-Influence of steel slag-silica fume composite mineral admixture on the propertiesof concrete.
[5] R.PadmaPriya,V.K.Bupesh Raja-(2015) study on replacement of coarse aggregate by steel slag &fine aggregate by manufacturing sand in concrete.volume 8,2015.
[6] Chinnaraju.K, et al., “Study on concrete using steel slag as coarse aggregate replacement and eco sandas fine aggregate” International journal of research in engineering and advanced technology,2013, 1,1-6.
[7] Al-Jabri K S, Al-Oraimi S K, Al-Saidy A H and Hisada M (2009) Copper slag as sand replacement for high performance concrete. CemConcr Compos 31:483–88.
[8] Deepika K P(2016) -Utilization of copper slag as a partial replacement of fine aggregate in concrete-issue 10,volume 3,October 2016
[9] Khanzadi M and Behnood A (2009) Mechanical properties of high-strength concrete incorporating copper slag as coarse aggregate. Constr Build Mater**23**(6):2183–88.
[10] Gorai, B. and Jana, R.K. Premchand (2002) Characteristics and utilization of copper slag, Resources Conservation a
[11] V.K.Bupesh Raja-(2015) study on replacement of coarse aggregate by steel slag &fine aggregate by manufacturing sand in concrete.volume 8.
[12] Manso, J.M., J.J. Gonzalez and J.A. Polanco, 2004. Electric arc furnace slag in concrete. J. Mater. Civil Eng. DOI: 10.1061/(ASCE)0899- 1561(2004)16:6(639)
[13] Anastasioue and Papayiannil(2006), “Criteria for the Use of Steel Slag Aggregates in Concrete", Measuring Book of Monitoring and Modeling Concrete Properties.
[14] Song HW, Saraswathy V. Studies on the corrosion resistance of reinforced steel in concrete with ground granulated blast-furnace slag – an overview. J Hazard Mater 2006;138:226–33.
[15] İ.Yüksel,R.Siddique,Ö.Özkan,Influence of hightemperature on the proper- ties of concretes made with industrial by-products as fine aggregate replace- ment, Constr. Build.Mater. 25(2) (2011)967–972.
[16] R. R. Chavan& D .B .Kulkarni (July-Sept., 2013.), Performance of Copper Slag on strength properties as partial replace of fine aggregate in concrete mix design, International Journal of Advanced Engineering Research and Studies/II/IV/ pp.95-98.
[17] Shoya M, Nagataki S, Tomosawa F, Sugita S, Tsukinaga Y. Freezing and thawing
[18] resistance of concrete with excessive bleeding and its improvement. In Proceedings of the fourth CANMET/ACI international conference on durability of concrete, vol. 170(45), 1997. p. 879–98 [special publication].
[19] N.K.S.Pundhir, et al ‘Use of copper slag as construction material in bituminous pavements’, Journal of Scientific & Industrial Research, vol 64 (2005).



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