International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 08 | Aug -2017 www.irjet.net p-ISSN: 2395-0072

# BEHAVIOUR ASPECTS OF COPPER SLAG AND STEEL FIBERS IN CONCRETE SUBJECTED TO DESTRUCTIVE AND NON DESTRUCTIVE TESTS

**S.RAGHU[1], MR.K.NEHEMIYA[2], MR.K.PRASAD[3]**

*[1]PG. student, DMS SVH College of engineering, MACHILIPATNAM, Andhra Pradesh, India.*
*[2]M-TECH, Assistant professor, DMS SVH College of engineering, MACHILIPATNAM, Andhra Pradesh, India.*
*[3]M-TECH, Assistant professor, DVR & Dr.H.S MIC College of engineering, Andhra Pradesh, India.*

---

**Abstract**: *Now–a-days the availability of sand is becoming more difficult for the constructions. Sand plays a vital role in the mixing of a concrete. So many researchers investigated that silica ($sio_2$) composition is used as a replacement of fine aggregate. The materials like fly ash, stone dust, Copper Slag are used. Copper slag is the waste material which comes from the copper. The decomposition of copper slag is very difficult, so if it is used it will decrease the pollution.*

*In this paper, Copper slag is used in different proportions such as 20%, 30%, 40%,and 50% as a partial replacement of fine aggregate for casting cubes, prisms and beams in order to determine the strength parameters such as compressive, split tensile and flexure (destructive and non destructive tests such as Ultrasonic pulse velocity and Rebound Hammer ). From this tests, the optimum percentage of copper slag is determined. Later, the steel fibers of different proportions such as 0.5%, 1%, 1.5% by volume of cement are added to the optimum percentage of copper slag in order to observe its impact on strength thereby calculating the optimum percentage of steel fiber. Using this optimum percentage, beams were casted of size 130cmx20cmx20cm in order to observe the flexural behaviour.*

**KEY WORDS: Copper slag, Crimped Steel fibers, HYSD steel, Flexural behaviour, Split tensile strength, UPV, Rebound hammer.**

## 1.0 Introduction

Copper slag is the waste material which comes from copper. Many researches told that copper slag is used as partial replacement for fine aggregate in the concrete mix. It is the waste product of copper from Sterlite Industries India Ltd, Tuticorin. The safe disposal of this waste is a lack, costly and causes environmental pollution. The use of copper slag in cement and concrete provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of copper slag is produced. Although copper slag is widely used in the sand blasting industry and in the manufacturing of abrasive tools, the remainder is disposed of without any further reuse or reclamation. Copper slag possesses mechanical and chemical characteristics that qualify the material to be used in concrete as a partial replacement for Portland cement or as a substitute for aggregates.

Addition of adequate fibers will improve tensile strength. Some of the important effects of fibers in concrete are: Increasing tensile strength, preventing the crack development, and increasing the toughness of concrete. The reason for extensive use of steel fibers is that it provides good workability and can be moulded to any shape.

### 1.1 Objectives

1. To study the strength parameters such as compressive, split tensile, Flexural strength (destructive), UPV, rebound hammer value (Non destructive) by replacing copper slag as a partial replacement of fine aggregate.
2. The test results obtained can be compared to the nominal concrete.
3. Casting of beams with optimum copper slag and optimum steel fibers.
4. The test results obtained can be compared to the nominal concrete beam.

## 2.0 Literature review

Washington Almeida, Mouraet.al studied various strength properties of concrete (compressive and split tensile strength) by using copper slag as partial replacement of sand. The results showed that the strength properties increase when compared to normal concrete.

Mazen Musmar studied the effect of addition of steel fibers in concrete and found improved mechanical

properties of concrete such as Tensile strength, impact strength, and toughness.

Binayaet.al studied the strength and durability properties of M20 and M30 grade copper slag concrete. The results showed that addition of copper slag increases the density of concrete there by increasing the self-weight.

**3.0 Materials:**

**3.1Coarse aggregate**:

The aggregate which retains on 4.75mm IS sieve is called coarse aggregate. The properties are shown in table1.

**Table1: Physical properties of coarse aggregate**

| S. No | Property | Result |
|---|---|---|
| 1 | Specific Gravity | 2.62 |
| 2 | Fineness modulus | 6.58 |
| 3 | Water absorption | 0.55% |

**3.2 Fine aggregate**:

The aggregate which passes through 4.75mm IS sieve is called fine aggregate. The properties are tabulated in table2.

**Table2: Physical properties of fine aggregate**

| S. No | Property | Result |
|---|---|---|
| 1 | Specific Gravity | 2.69 |
| 2 | Fineness modulus | 2.58 |
| 3 | Water absorption | 0.5% |

**3.3 Cement**

Ordinary Portland cement of 53grade is used. The Properties of cement are shown in table3.

**Table 3: Physical properties of cement**

| S. NO | Property | Result |
|---|---|---|
| 1 | Setting times<br>a)Initial<br>b)Final | <br>40min<br>570min |
| 2 | Normal consistency | 29% |
| 3 | Specific Gravity | 3.12 |
| 4 | Fineness modulus | 4 |
| 5 | Soundness | 5mm |

**3.4 Copper slag**:

Copper slag is irregular black and granular in nature. The Properties of copper slag are shown in table 4.

**Table 4: Physical properties of copper slag**

| S.NO | Property | Result |
|---|---|---|
| 1 | Specific gravity | 3.58 |
| 2 | Fineness modulus | 5.162 |
| 3 | Water absorption | 0.34% |
| 4 | Maximum size | 4.75mm |

**Fig.1: Copper slag**

**3.5 Crimped steel fibers**

Crimped steel fibers of diameter 0.5mm and length 30mm with aspect ratio 60 is used.

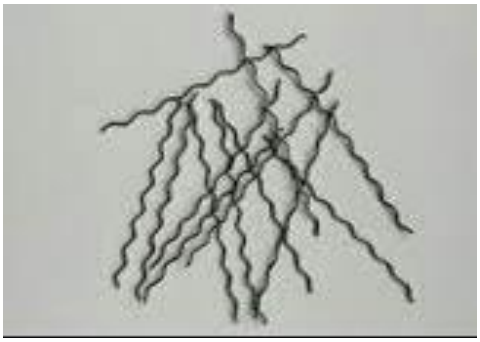

**Fig.2: Crimped steel fibers**

**3.6 Water**

Clean potable water available in laboratory is used to satisfy all the requirements as per IS 456-2000.

**4.0Methodology**

- For manufacturing of copper slag admixed concrete, initially study the properties of different materials used. Later cubes, prisms and cylinders are casted with different percentages of copper slag such as 10%, 20%, 30%, 40% and 50% as a partial replacement for fine aggregate in concrete mix. From this, the optimum percentage compression strength values are determined.
- Then steel fibers of different percentages such as 0.5%, 1% and 1.5% by weight of cement are added to the optimum copper slag admixed concrete. From this, the optimum steel fiber percentage is determined.
- Optimum percentage of copper slag and steel fibers were used to cast beams of size 130cmx20cmx20cm in order to observe the flexural crack behaviour.

**4.1 Experimental program**

- In this work, for manufacturing copper slag admixed concrete, M-25 grade of concrete is used.
- Copper slag as partial replacement for fine aggregate in the mix with different percentages such as 10%, 20%, 30%, 40% and 50%.
- Then cubes, prisms and cylinders are casted with that percentage values.
- Now, firstly do non destructive tests such as UPV and rebound hammer test. Later, destructive tests are conducted such as compression test for cubes and tensile strength test for cylinders and flexure test for prisms.
- For that, steel fibers length 30mm and diameter 0.5mm are added to the mix in different proportions such as 0.5%, 1%, 1.5% by weight of cement.
- Then again tests are conducted for the specimens thereby, the optimum percentage of strength value of copper slag with steel fiber are determined.
- For this optimum percentage, beams of size 130cmx20cmx20cm were casted to observe flexural crack pattern & & finally compare the results with nominal concrete beams.

**Fig.3: Casting of specimen**

**Fig.4: Finishing of specimen**

**5.0 Test results**

**5.1 Non destructive tests**

**(i) Ultra pulse velocity test:** In this test, the strength and quality of concrete or rock can be assessed by measuring the velocity of an ultra sonic pulse passing through a concrete structure.

**Table 5: UPV values for 7 & 28 days with different copper slag percentages**

| Percentage of copper slag | Velocity (km/sec) | |
|---|---|---|
| | 7 days | 28 days |
| 10% | 4.532 | 4.75 |
| 20% | 4.739 | 4.95 |
| 30% | 4.032 | 5.181 |
| 40% | 4.348 | 5.025 |
| 50% | 4.831 | 4.082 |

**Table 6: Velocity criterion for concrete quality grading (As per IS: 13311-Part1)**

| S.NO | Pulse velocity by cross-probing, km/sec | Concrete quality grading |
|---|---|---|
| 1 | Above 4.5 | Excellent |
| 2 | 3.5 to 4.5 | Good |
| 3 | 3.0 to 3.5 | Medium |
| 4 | Below 3.0 | Doubtful |

**(ii) Rebound Hammer:** A device used to measure the elastic properties or strength of concrete mainly surface hardness and penetration resistance.

**Table 7: Rebound strength of cubes for 7 & 28 days with different copper slag percentages**

| Percentage of copper slag | 7days | | 28days | |
|---|---|---|---|---|
| | Rebound number | Rebound strength | Rebound number | Rebound strength |
| 10% | 10 | 15 | 16 | 32 |
| 20% | 10 | 17 | 16 | 34 |
| 30% | 10 | 21 | 18 | 40 |
| 40% | 22 | 16 | 16 | 34 |
| 50% | 10 | 16 | 16 | 34 |

**Table 8: Rebound strength of cylinders for 7 & 28 days with different copper slag percentages**

| Percentage of copper slag | 7days | | 28days | |
|---|---|---|---|---|
| | Rebound number | Rebound strength | Rebound number | Rebound strength |
| 10% | 10 | 15 | 16 | 32 |
| 20% | 10 | 15 | 16 | 32 |
| 30% | 10 | 15 | 18 | 36 |
| 40% | 20 | 16 | 14 | 26 |
| 50% | 16 | 20 | 14 | 26 |

### 5.2 Destructive tests

**Compressive strength**

The compressive strength test is carried out on a specimen (cube) of size 10cmx10cmx10cm for 7&28days and the test results obtained can be compared with that of conventional concrete.

### 5.3 Split tensile strength

The split strength test is conducted on a specimen (cylinder)having length 30cm and diameter 15cm for 7 &28 days and the test results obtained can be compared with that of conventional concrete.

### 5.4 Flexural strength

The flexural strength test is conducted on a specimen (prism) of size 50cmx10cmx10cm for 7 & 28 days and the test results obtained can be compared with that of conventional concrete.

**Test results for different percentages of copper slag**

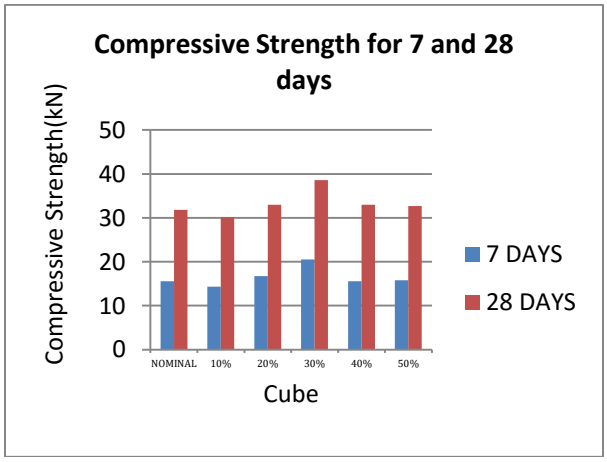


**Fig.5: compressive strength for 7 & 28days**

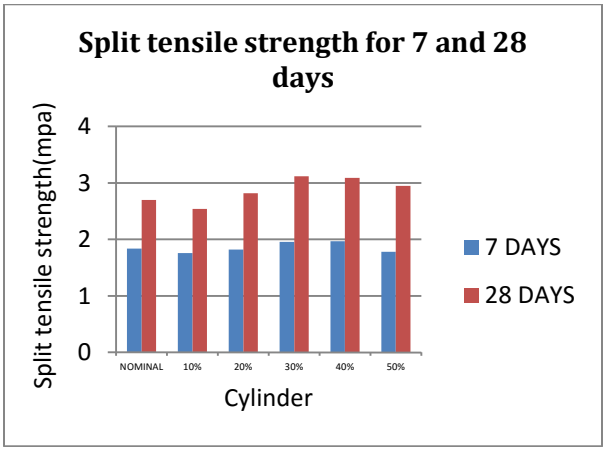


**Fig.6: split tensile strength for 7 & 28 days**

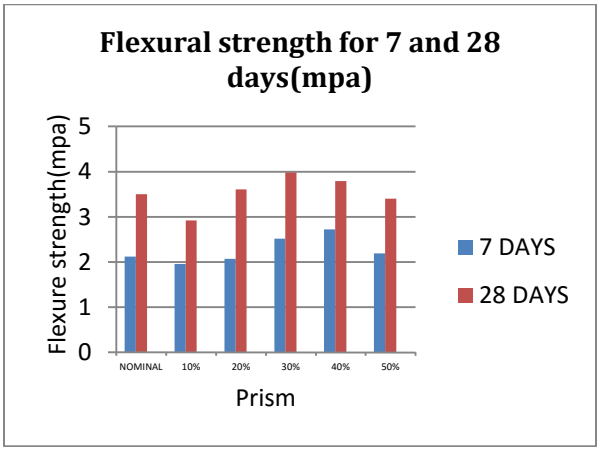


**Fig.7: Flexural strength for 7 & 28 days**

From the above graphs, it is observed that the optimum percentage of copper slag occurs at 30%. For this 30% of copper slag, different percentages of steel fibers such as 0.5%, 1%, 1.5% by weight of cement were added in order to observe its strength parameters for 7 and 28 days and the test results obtained can be compared with that of nominal concrete. From this, optimum percentage of steel fibers with optimum percentage of copper slag were determined.

**Test Results for optimum copper slag (30%) with different percentages of steel fibers**

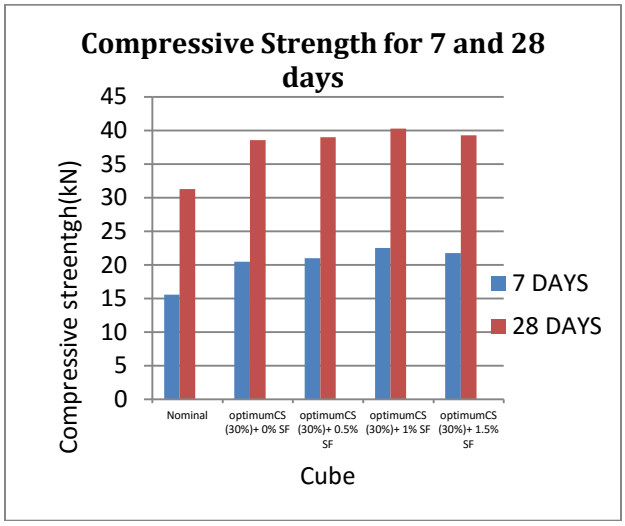


**Fig.8: Compressive strength for 7 & 28 days**

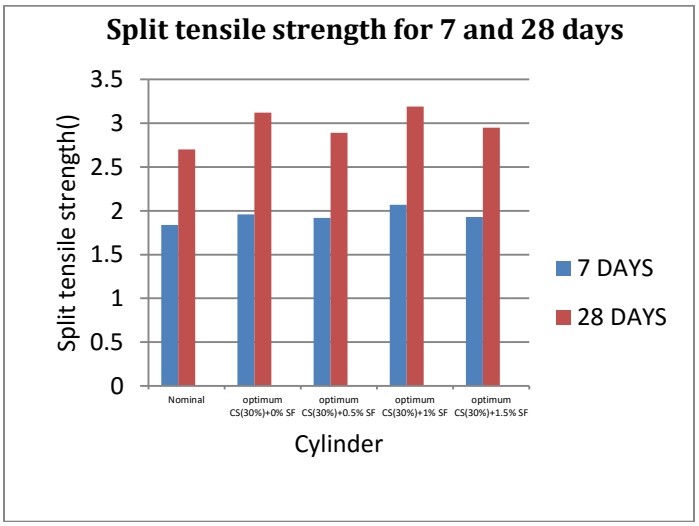


**Fig.9: Split tensile strength for 7 & 28 days**

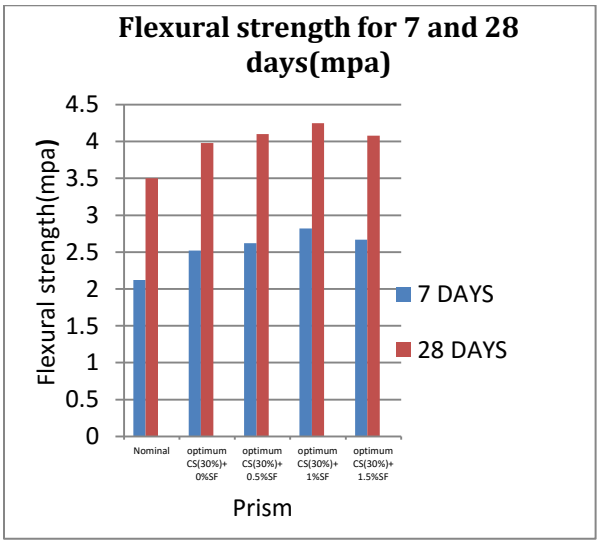


**Fig.10: Flexural strength for 7 & 28 days**

**Table 9: UPV values for 7 & 28 days with optimum copper slag percentage and different percentages of steel fibers**

| Optimum copper slag + percentage of steel fibers | Velocity (km/sec) | |
|---|---|---|
| | 7days | 28days |
| CS(30%)+SF(0.5%) | 4.545 | 4.73 |
| CS(30%)+SF(1%) | 4.608 | 4.93 |
| CS(30%)+SF(1.5%) | 4.219 | 4.45 |

**Table 10: Rebound number value of cubes for 7 & 28 days with optimum copper slag percentage and different percentages of steel fibers**

| Optimum copper slag + percentage of steel fibers | 7days | | 28days | |
|---|---|---|---|---|
| | Rebound number | Rebound strength | Rebound number | Rebound strength |
| CS(30%)+SF(0.5%) | 10 | 21 | 16 | 39 |
| CS(30%)+SF(1%) | 20 | 24 | 26 | 42 |
| CS(30%)+SF(1.5%) | 10 | 22 | 16 | 40 |

**Table 11: Rebound number value of cylinders for 7 & 28 days with optimum copper slag percentage and different percentages of steel fibers**

| Optimum copper slag + percentage of steel fibers | 7days | | 28days | |
|---|---|---|---|---|
| | Rebound number | Rebound strength | Rebound number | Rebound strength |
| CS(30%)+SF(0.5%) | 10 | 21 | 24 | 38 |
| CS(30%)+SF(1%) | 20 | 24 | 26 | 42 |
| CS(30%)+SF(1.5%) | 26 | 41 | 26 | 42 |

Based on above observation, the optimum 30% of copper slag with addition of 1% of steel fibers yields the highest strengths and it is used for casting beams of size 130cmx20cmx20cm in order to observe its flexural behaviour and also to determine the load carrying capacity.

Two beams were casted out of one is nominal beam and other one is optimum percentage of copper slag with steel fiber (30%CS+1%SF). The load carrying capacity is high for beam with optimum copper slag percentage (30%) with 1% of steel fiber and shown.

**Table 12: Reinforcement detailing of beam**

| S.NO | Type of steel | No. of bars | Diameter of bar(mm) |
|---|---|---|---|
| 1 | Tension steel | 5 | 12 |
| 2 | Compression steel | 2 | 8 |
| 3 | Stirrups | 2-Legged | 6 |

Design load = 150 KN
**M-25 mix**
$F_{ck}$ = 42.5mpa
Fe-415 steel
Cover = 20mm

% of tension steel = $100A_{st}/bd$= 1.41%
% of compression steel = $100A_{sc}/bd$ = 0.25%

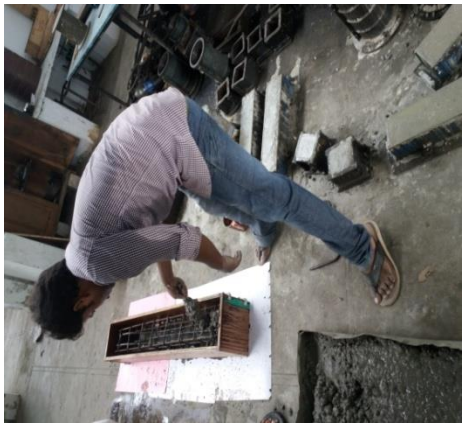

**Fig.11: Casting of Beam**

**Fig 12: Testing of beam**

**Table 13: Test results of beam**

| S.NO | Type of beam | First cracking Load (KN) | Ultimate Load (KN) | Maximum deflection (mm) |
|---|---|---|---|---|
| 1 | Nominal | 25 | 90 | 4.5 |
| 2 | Optimum (CS+SF) | 32.5 | 135 | 4.9 |

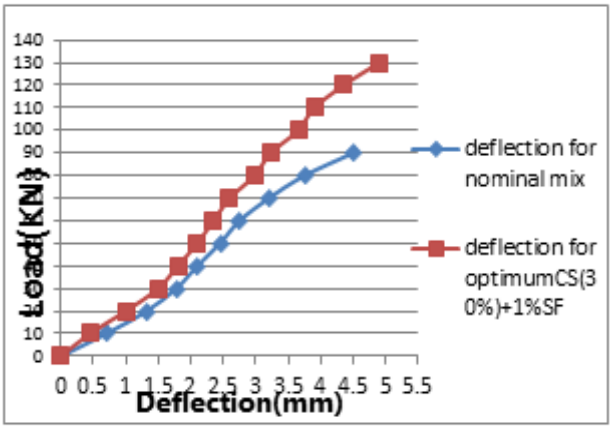


**Fig 14: Load vs deflection cure for beam**

As per IS: 456-2000, allowable deflection = Span/250 = 5.2mm

**Conclusion**:

- The compressive strength, split tensile strength & flexure strength optimum values occurs at 30% replacement of copper slag and increase up to 21.25%, 15.5% & 13.7% respectively as that of nominal concrete.
- From the experimental study, beam with copper slag and steel fibers posses higher strength than nominal beam, hence it is recommended for normal site work.
- The compressive strength, split tensile strength & flexure strength 0f 30% replacement of copper slag occurs at 1% of steel fibers and increases up to 26.5%, 18% & 21.42% respectively as that of nominal concrete.
- The beam with copper slag and steel fibers shows better resistance at 1st cracking load and ultimate load values are 30% & 50% higher than the nominal concrete beam.

**REFERENCES**:

1. VIMARSH S.P paper on "Study on strength properties of fibre reinforced concrete by partial replacement of sand by copper slag ", ISSN: 2348-7607, Vol.2, Issue 1, April – September 2014.

2. BINAYA PATNAIK, SESHADRI SEKHAR T AND SRINIVAS RAO , " Usage of copper slag as fine aggregate in copper slag admixed concrete", Vol.5, Issue 6, sep- Nov 2015.

3. BINAYA PATNAIK, SESHADRI SEKHAR T AND SRINIVAS RAO, "An experimental investigation on strength properties of copper slag fiber reinforced concrete", Vol.10, No.20, PP.9246-9257.

4. ISHIMARU K., MIZUGUCHI H., HASHIMOTO C., UEDA T., FUJITA K. AND OHMI M. 2005 "Properties of copper slag and second class fly ash as a part of fine aggregate" journal of society material science Japan. 54(8): 828-833.

5. BINAYA PATNAIK et al. (2015), "Strength and Durability Properties of Copper Slag Admixed Concrete", International Journal of Research in Engineering and Technology, Volume 4, 158-166.

6. AMIT RANA (2013), Some Studies on "Steel Fibre Reinforced Concrete", *International Journal of Emerging Technology and Advanced Engineering,* Volume 3, 120-127.

7. WASHINGTON ALMEIDA, MOURA JARDEL, PEREIRA GONC, and MONICA BATISTA LEITE LIMA. 2007 "Copper slag waste as a supplementary cementing material to concrete". J. Mater. Sci. 42: 2226-2230.

8. AL-JABRI K., TAHA R. and AL-GHASSANI M. 2005 "Use of copper slag and cement by-pass dust as cementitious materials."Cement, Concrete Aggregates 24(1): 7-12.

9. TAEB, A. and FAGHIHI, S. "Utilization of copper slag in the cement industry", Zement Kalk Gips International, Vol.55, No.4, pp. 98-100, 2002.

10. WU, W., ZHANG, W. and Ma, G. "Optimum content of copper slag as a fine aggregate in high strength concrete", Material design, Vol.31, No.6, pp. 2878-2883,2010.

**ACKNOWLEDGEMENT:**

The author would like to thank Mr. K.NEHEMIYA, M.TECH, ASST.PROF, DMS SVH Engineering College, MACHILIPATNAM, India. For his extensive guidance and support. The author would also like to thank the Department of Civil Engineering, lab technicians of DMS SVH College of Engineering, MACHILIPATNAM, Andhra Pradesh, India to make this work successful.

**BIOGRAPHIES**

S.Raghu, PG student, Structural Engineering,DMS SVH College of Engineering Machilipatnam. KrishnaDistrict, Andhra pradesh, India.

Mr. K.Nehemiya, Obtained his M.TECH from JNTUK. He is having 5years of experience in teaching and he has several publications in national and international journals. His areas of interest is RCC, PSC and Geo-polymer concrete.

Mr.K.Prasad, obtained his M.TECH from DVR & Dr.H.S Mic College of technology. He is having 2 years experience in teaching. His areas of interest is DRCS, DSS, SM & SA.