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# Flexural Behaviour of Copper Slag Concrete

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## Abstract

This paper reports the observations of an experimental investigation conducted to study the effect of copper slag, which is used as replacement of fine aggregate in concrete. Copper slag is produced in the smelting process during the extraction of copper from its ore. It is made from granulated slag and is used as a blasting grit. Every one ton of copper generates about 2.5 to 3.5 tons of copper slag. This waste material has a promising application in construction Industry. This paper focuses on the application of copper slag as replacement of fine aggregate in concrete. Copper slag is used in 10%, 20%, 30%, 40%, 50%, 60% and 100%. To enhance the mechanical strengths, polypropylene fiber is added in percentages of 0%, 0.1%, 0.2%, 0.3% and 0.4%. Study of the results clearly present the effect of Copper slag and polypropylene fibers on the flexural strength of concrete.

**Key Words:** Copper slag, Flexure, Bending, Deflection, Fine aggregate, Polypropylene, Fibers

## Introduction

In India there is a great demand for the river sand by the construction industry. But now a days, there is acute scarcity of natural river sand and it has become a difficult problem to crack and find a suitable replacement material. While the demand for natural resources is increasing, waste being generated by industries is also increasing affecting the ecology[1]. Hence, there is a need to develop materials that would save the natural resources worldwide. Development of innovative materials, helps in sustainable development of construction and makes use of waste materials to compensate the scarcity of natural resources contributing in conserving environment[2,3].

**Copper Slag**

Copper slag is an industrial waste by product produced during the smelting process of the ore of copper. It is used as blasting grit. It is slowly gaining popularity in construction industry as a filler material in place of sand. It serves a replacement material for sand in concrete. Addition of copper slag improves the properties of concrete and also serves as a recycled waste product. Copper slag can be used in making masonry blocks, in bituminous pavements[4]. It can be more widely used as a abrasive material to remove the rust, surface coatings and other impurities etc because of it high density of 2.8 to 3.8 g/cc, high hardness and low free silica content[5,6]. Copper slag is also used in geomagnetic research, in sand compaction file etc.

**Polypropylene Fiber**

Polypropylene fiber used as secondary reinforcement help in reducing shrinkage and control cracking. Polypropylene fibers can improve impact and abrasion resistance, structural strength, freeze-thaw resistance, fire resistance, ductility and durability. Addition of fibers reduce steel reinforcement requirement and controls the crack widths by acting as crack arresters[7,8]. Fibers hold the concrete together and prevent the spreading and widening of cracks. A crack can open up when the tensile stresses in concrete exceed the tensile strength of fibers. When the polypropylene fibers are longer, then there exists a stronger bond between fibers and cement paste, thus necessitating greater pull out strength. Longer fibers can be used when larger aggregates are used and also when the structural strength has to be improved while short fibers can be used for light weight aggregates. Fibrillated fibers of length 0.5 to 2.5 inches are commercially available.

**Experimental Program**

Hence, in this project copper slag is proposed as a replacement material for fine aggregate and to establish its performance, a series of tests are conducted by varying the percentage of copper slag as 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%. To improve the mechanical strengths, polypropylene fibers are added in the volume content of 0%, 0.1%, 0.2%, 0.3% and 0.4%. A series of tests are carried out for various contents of copper slag and polypropylene fiber and the test results are compared with the conventional concrete made of Ordinary Portland Cement and natural river sand.

**Materials**

***Cement***

The cement used in the study is ordinary Portland cement of 53 grade. It is tested for physical properties as per IS 12269: 2013 standard. The preliminary test results of the cement are tabulated in table 1.

**Table 1:** Properties of Cement

| PROPERTY | VALUES |
|---|---|
| Specific gravity | 3.18 |
| Normal consistency | 30% |
| Initial setting time | 30mins |

***Fine aggregate***

Locally available river sand is used as fine aggregate in this investigation. Sand passing through 4.75 mm was taken. The preliminary test results of the sand are tabulated in table 2.

**Table 2:** Properties of Sand

| PROPERTY | VALUES |
|---|---|
| Specific gravity | 2.55 |
| Fineness modulus | 3.25 |
| Zone | II |

***Coarse aggregate***

Crushed stone of 20 mm size was used as coarse aggregate. Physical properties are tested as per IS 12269: 2013 standard. The specific gravity of coarse aggregate is 2.40.

***Copper slag***

Copper slag obtained from Mariya Industries, Chennai which has specific gravity of 2.69 is used.

***Super plasticizer***

Commercially available Sulphonated Naphthalene Formaldehyde based super plasticizer (CONPLAST SP 430) was used as chemical admixture to enhance the workability of the concrete.

***Water***

Ordinary Potable water is used for casting and curing.

***Mix Proportion***

For this research work, M30 grade concrete was used. Mix design was carried out as per IS:10262-2000. The mix ratio are given in the table 4.

**Table 3:** Mix Proportion

| W/C ratio | Cement | Fine Aggregate | Coarse Aggregate |
|---|---|---|---|
| 0.40 | 1 | 1.05 | 2.38 |

**Casting of Specimens**

Specimens of size 100 x 100 x 500 mm are cast and cured in water for a period of 28 days. Totally

**Testing**

The specimens are tested under two point loading in a Universal Testing Machine of 40 tons capacity. The test set up is shown in the fig below.


**Figure 1:** Test Set Up

**Figure 2:** Measurement of Strains

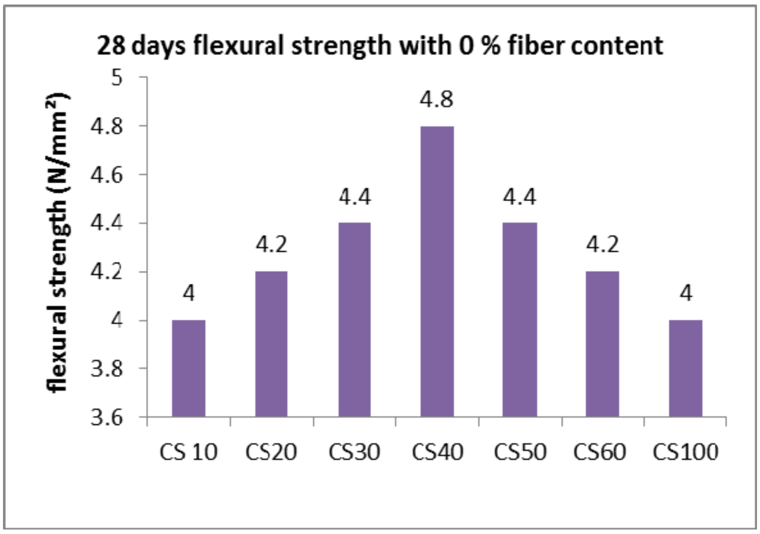
A dial gauge (least count of 0.01mm) is kept under the specimen at centre of the span to measure mid span deflections. The deflections are measured at a intervals of 2.0 kN. The load is increased until the specimen fails and the failure load is recorded. The distance between the line of fracture and the position of nearest support, along the central line at the bottom surface was measured as ‘a’. The flexure strength for the two point loading is calculated.

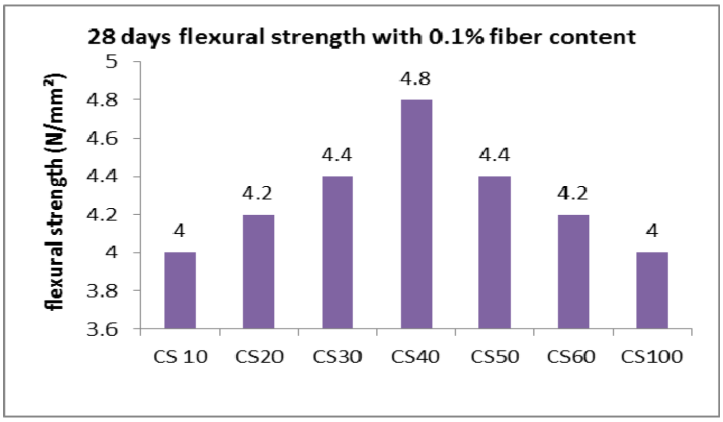
From the series of experimental investigations conducted, the failure load, midspan deflection and crack patterns are noted. The flexural strengths obtained for different specimens is presented in table 4 below.

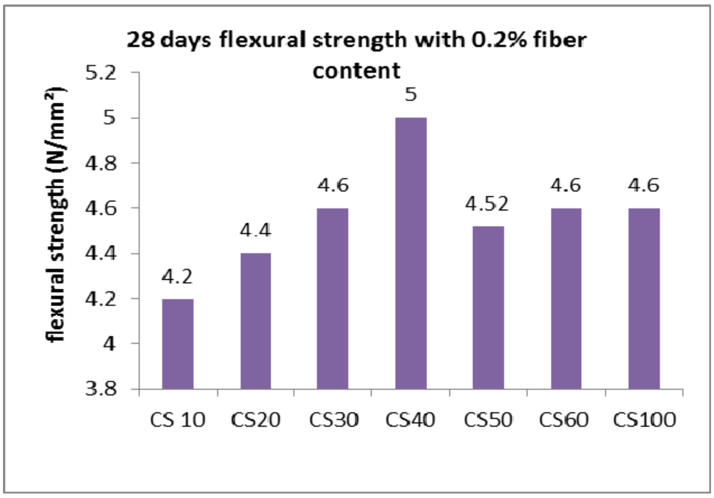
**Table 4:** Flexural Strength

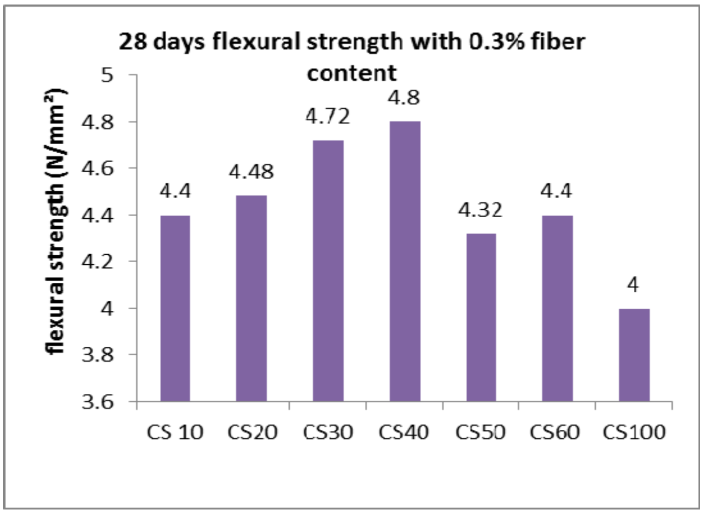
| **SPECIMEN** | **28 days Flexural Load kN** | | | | | | |
|---|---|---|---|---|---|---|---|
| | CS 10 | CS20 | CS30 | CS40 | CS50 | CS60 | CS100 |
| PP 0 | 4 | 4.2 | 4.4 | 4.8 | 4.4 | 4.2 | 4 |
| PP0.1 | 4.2 | 4.4 | 4.6 | 5 | 4.52 | 4.6 | 4.6 |
| PP 0.2 | 4.4 | 4.8 | 5 | 5.2 | 4.6 | 4.8 | 4.2 |
| PP 0.3 | 4.4 | 4.48 | 4.72 | 4.8 | 4.32 | 4.4 | 4 |
| PP 0.4 | 4 | 4.12 | 4.32 | 4.4 | 4.32 | 4 | 4 |

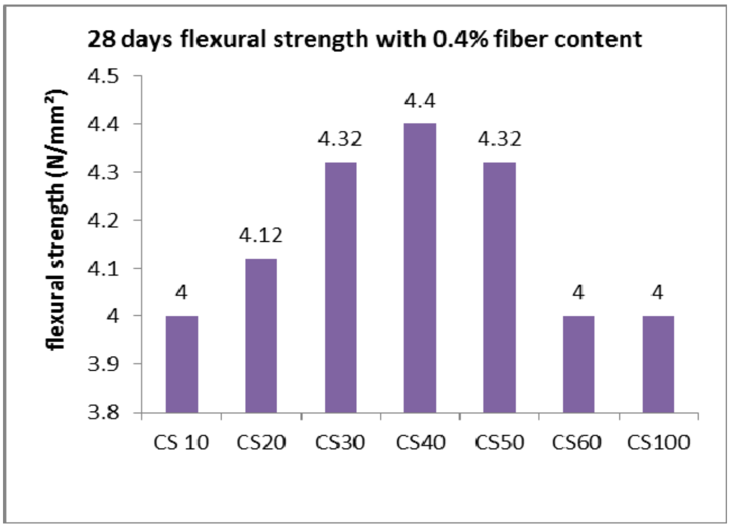
**i) Effect of Copper slag**

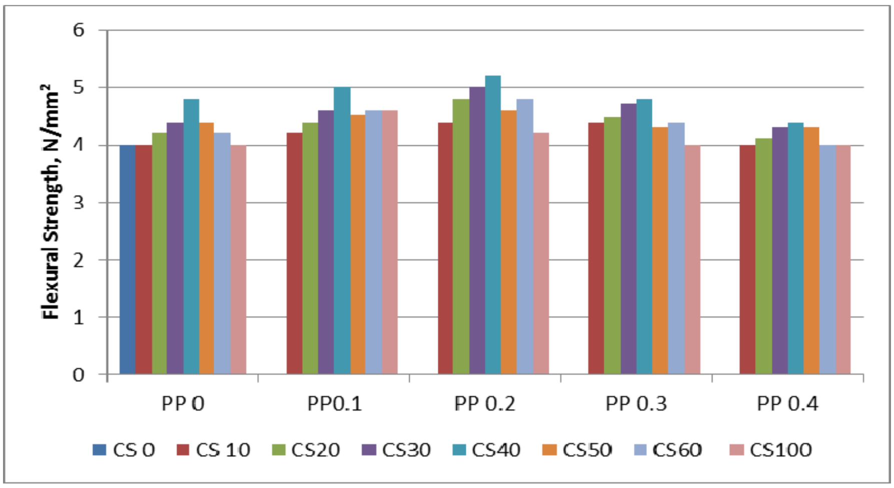


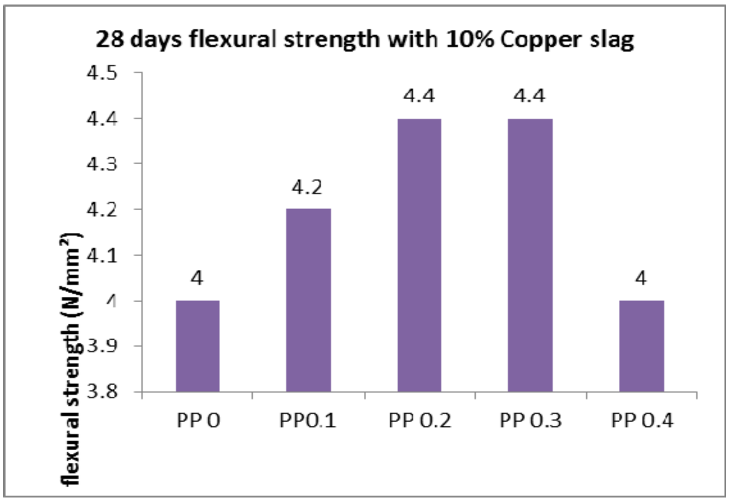



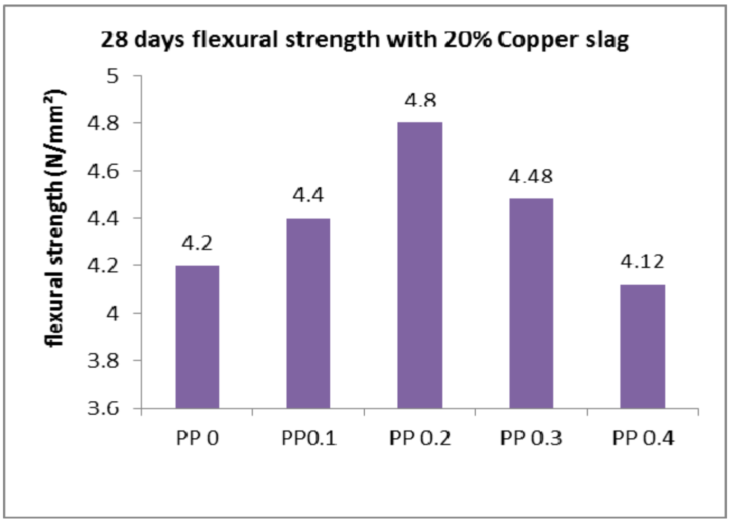

28 days flexural strength with 0.3% fiber content
flexural strength (N/mm²)
5
4.8
4.6
4.4
4.2
4
3.8
3.6
4.4
4.48
4.72
4.8
4.32
4.4
4
CS 10
CS20
CS30
CS40
CS50
CS60
CS100

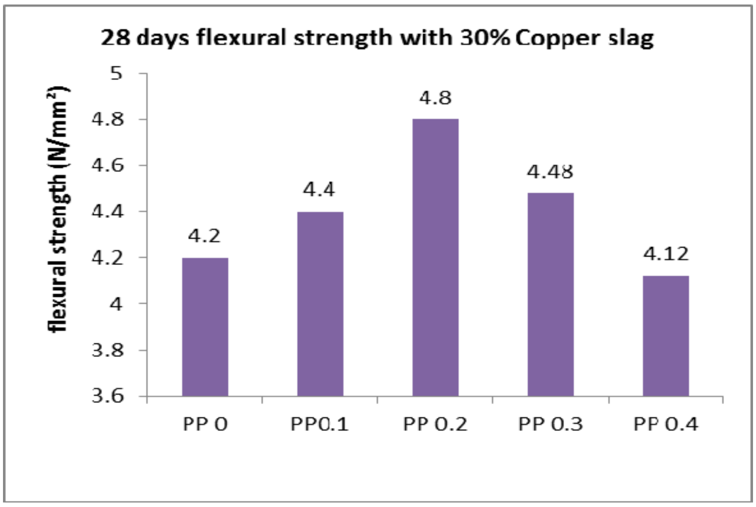

28 days flexural strength with 0.4% fiber content
flexural strength (N/mm²)
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
4
4.12
4.32
4.4
4.32
4
4
CS 10
CS20
CS30
CS40
CS50
CS60
CS100

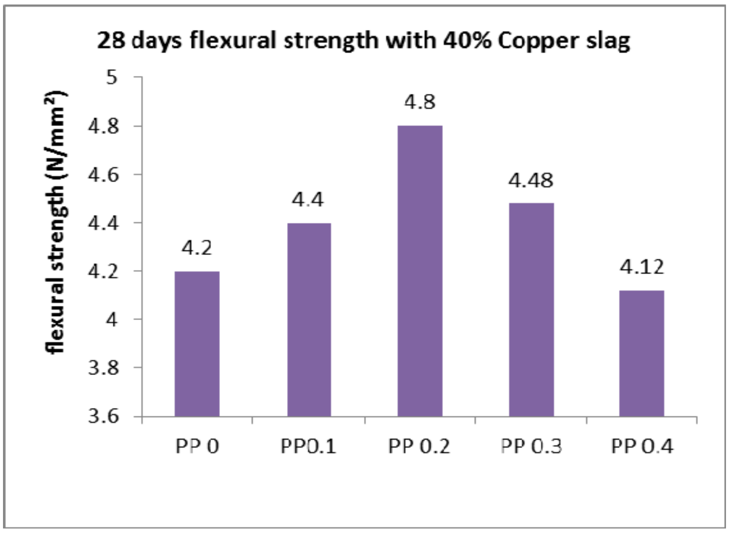

Flexural Strength, N/mm²
6
5
4
3
2
1
0
PP 0
PP0.1
PP 0.2
PP 0.3
PP 0.4
CS 0
CS 10
CS20
CS30
CS40
CS50
CS60
CS100

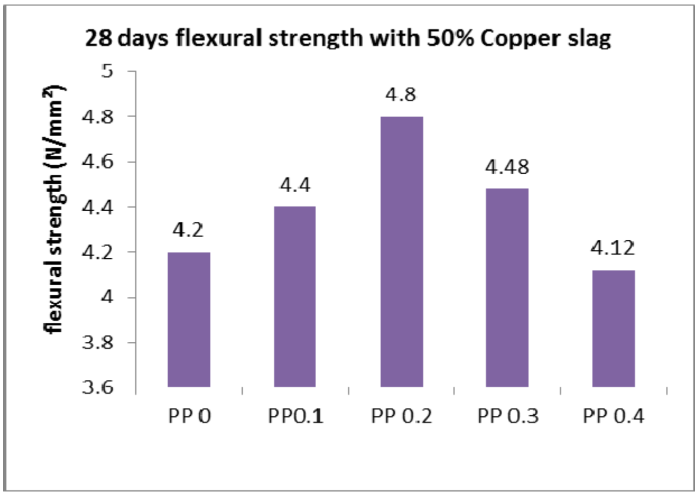
## Effect of Fibers

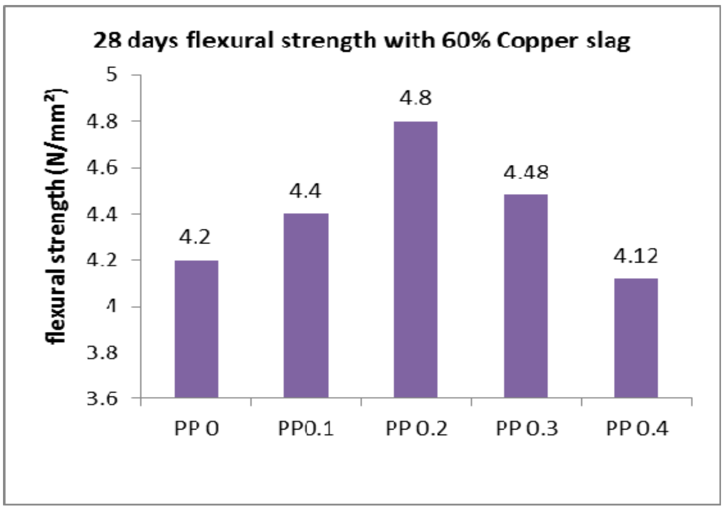


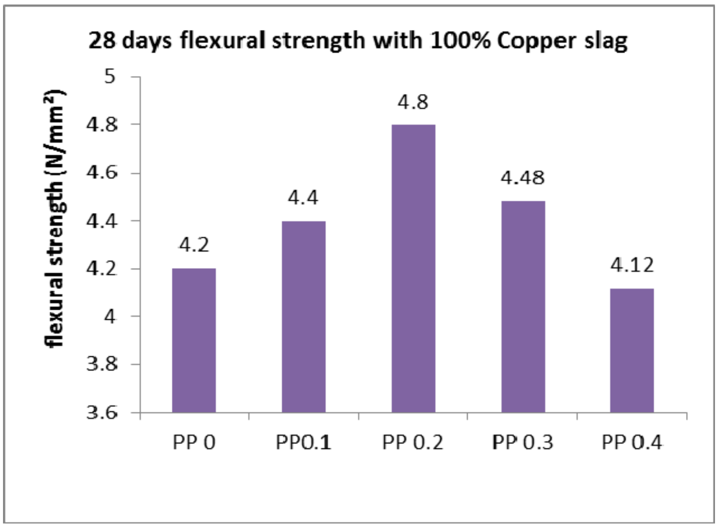



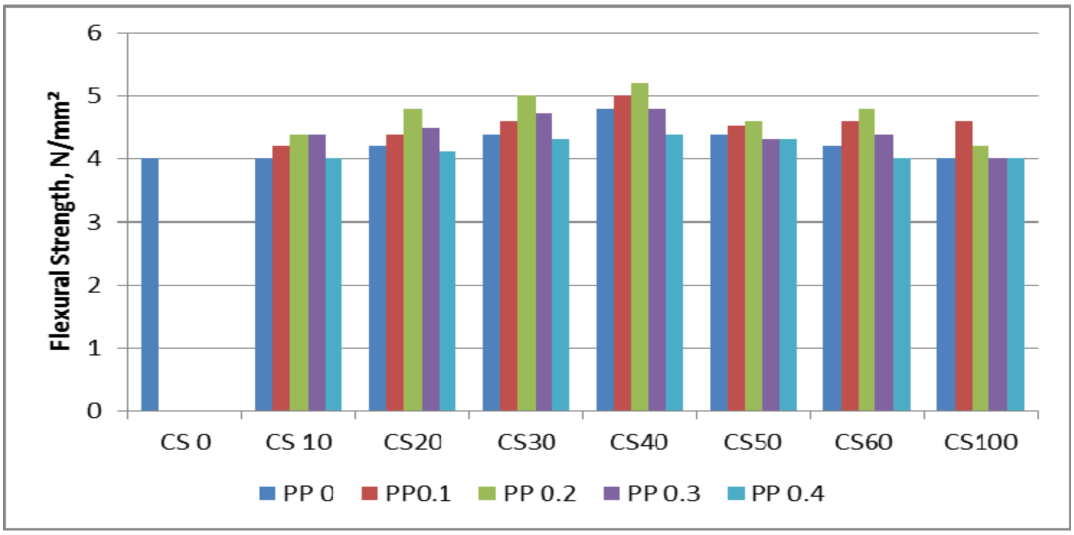




28 days flexural strength with 40% Copper slag
flexural strength (N/mm²)
5
4.8
4.6
4.4
4.2
4
3.8
3.6
4.2
4.4
4.8
4.48
4.12
PP 0
PP0.1
PP 0.2
PP 0.3
PP 0.4


28 days flexural strength with 50% Copper slag
flexural strength (N/mm²)
5
4.8
4.6
4.4
4.2
4
3.8
3.6
4.2
4.4
4.8
4.48
4.12
PP 0
PP0.1
PP 0.2
PP 0.3
PP 0.4

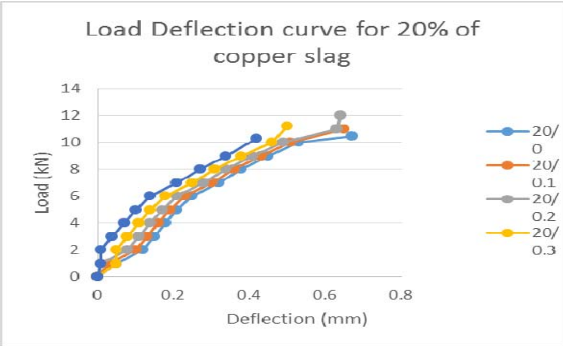

28 days flexural strength with 60% Copper slag
flexural strength (N/mm²)
5
4.8
4.6
4.4
4.2
4
3.8
3.6
4.2
4.4
4.8
4.48
4.12
PP 0
PP0.1
PP 0.2
PP 0.3
PP 0.4

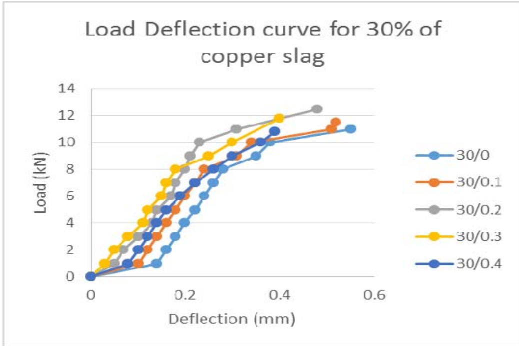


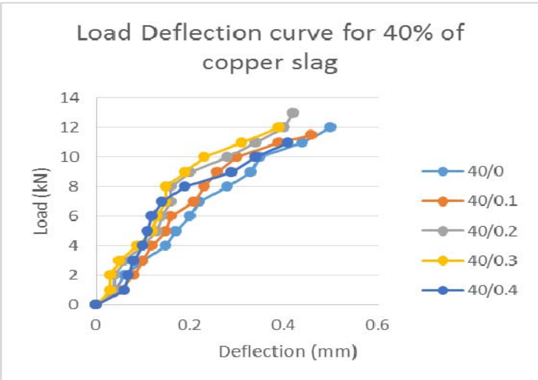



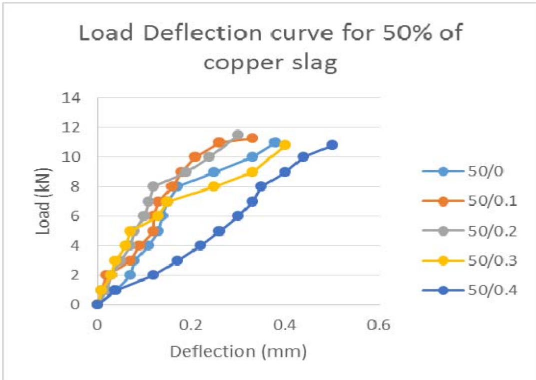

From the experimental results it is evidenced that the flexural strength increased with increase in copper slag content upto 40% but beyond 40% the strength started decreasing. Similarly, when polypropylene fibers were used, the flexural strength increased upto 0.2% and beyond 0.2%, the flexural strength decreased. The flexural strength was more than the control speciment with addtion of copper slag upto 60% and polypropylene fiber upto 0.3%.

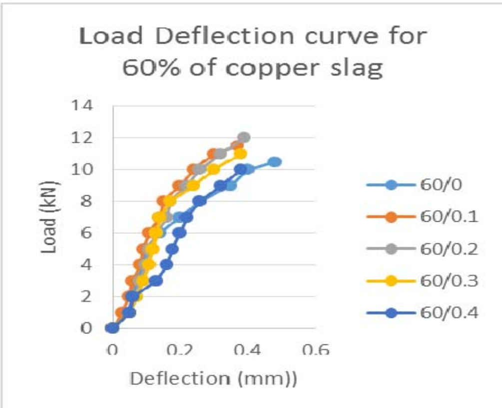
From the measurements made during loading, the load deflection curves are plotted as below.

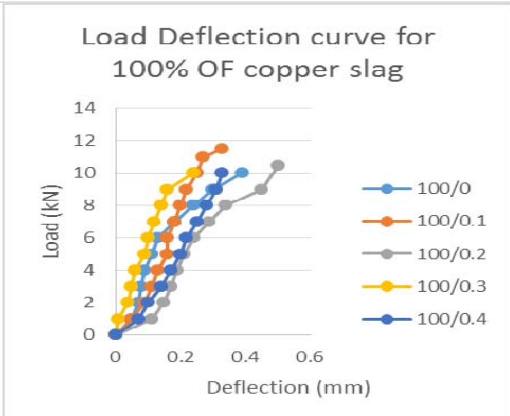



## Conclusions

1. Copper slag is an acceptable material for replacement of fine aggregate in concrete.
2. The optimum content of copper slag which can replace fine aggregate is found to be 40%
3. The optimum content of polypropylene fibers content is 0.2%.
4. The flexural strength when copper slag is used is higher than the conventional concrete due to its higher density, for all cases except for 100 % replacement.
5. The 28 days flexural strength obtained by replacing fine aggregate with copper slag is found to be increasing from 5% to 18 %.
6. For higher proportions of copper slag the flexure strength decreases.

7. Addition of polypropylene fibers improved the ductility of the beam.
8. No sudden failures are observed in all beams containing polypropylene fibers.

## Acknowledgements
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