Effect of Copper Slag on Strength of Polypropylene Fiber Reinforced Concrete

Dr.T.Ch.Madhavi[1], Arindam Mallick[2], Sohail M.B[3], Soumyadeep Nath[4], Mohit Jain[5]
[#] SRM University, Ramapuram, Chennai, Tamilnadu, India
[1]tcmadhvi@yahoo.com

***Abstract*—Due to exponential growth in the usage of concrete world over, there is a huge demand for natural river sand as construction material. Off late, this excessive consumption of sand led to acute shortage and led to slowing down of construction projects. Hence to protect the natural shore line, a necessity is felt to find suitable replacement material for sand in concrete as concrete is consumed second largest in the world. In this work copper slag which is an industrial waste is used as a replacement material for sand and its effect is studied on the strength of concrete. Also, to improve the strength and ductility, polypropylene fibers are added in the ratios of 0.1%, 0.2%, 0.3% and 0.4% content. The effect of copper slag is investigated by replacing fine aggregate in concrete in the proportions of 10%, 20%, 30%, 40%, 50% 60% and 100%. The results obtained are analyzed and presented.**

Keywords- Copper Slag, Compressive strength, Fine aggregate replacement, Polypropylene Fibers.

I. INTRODUCTION

Aggregates are important constituent of concrete. Aggregates occupy about 60 to 75% of the total volume of concrete. Fine aggregate used in concrete is generally river sand. Natural sand is generally being dredged or dug from the river or lake bed causing ecological imbalance. Use of artificial aggregates is expensive and hence an alternative material for river sand is being explored. Utilization of industrial waste as aggregates not only reduces the cost but also reduces the environmental pollution. Copper slag is one such material which can be effectively used as replacement for sand in concrete. Polypropylene fibers are included as an additive to improve the performance of concrete. In this paper, the effect of replacement of fine aggregate with copper slag in polypropylene fiber reinforced concrete is studied and the results are presented. .

II. COPPER SLAG AND POLYPROPYLENE

Copper slag is an industrial waste product produced in the smelting process during the production of copper from its ore. It has a promising future in making of concrete as full or partial replacement material for fine aggregate. Copper slag is generally used as grit for blast cleaning of rough surfaces or for removal of rust, paint etc. It is a black, glassy granular material. Copper slag has a bulk density of 1.70 to 1.90 g/cc, hardness between 6 to 7 MoH Scale. In this work, copper slag obtained from Sterlite Industries, Tuticorin is used.

Polyproplene is a non-synthetic thermoplastic polymer used as fiber for improving the performance of concrete even after cracking. Unlike steel fibers, these fibers are rust proof, alkali resistant, non-magnetic and have low thermal conductivity. They are safe and easy to handle. In this work, polypropylene fibers of type ENDURO HPP45 are used.

III. EXPERIMENTAL INVESTIGATIONS

To study the effect of copper slag on the strength of concrete, fine aggregate is replaced with copper slag in 10%, 20%, 30%, 40%, 50%,60%, 70%, 80%,90% and 100%. Polypropylene is included as an additive in volume fractions of 0.1%, 0.2%, 0.3% and 0.4%.

Ordinary Portland Cement of 53 grade is used. River sand conforming to Zone II is used as fine aggregate. Well graded crushed granite stone of size 20mm is used as coarse aggregate. Ordinary potable water free from salts is used for mixing. Super plasticizer CONPLAST SP430 is added to improve workability.

The concrete after thoroughly missing is placed in cube moulds of size 150 x 150 x 150 mm and demoulded after 24 hrs. The concrete cube specimens are cured in water for 28 days. The specimens are tested after 7 days and 28 days to study the early age strength and also the strength after hardening.

Fig 1. Placing Specimen in Compression testing machine

Fig. 2 Testing of Specimen

A. Testing

The specimens are tested for early age strength of 7days and also at 28 days after the concrete hardens. Prior to testing, the specimens are removed from the curing tank and surface water is wiped off. In surface dry condition the loose sand or other material is removed from the surface of the specimens and then they are tested in a compression testing machine of capacity 200 T. After ensuring that the axis of the specimen is carefully aligned to match with the center of the platens, load is applied at uniform rate of approximately 40 kg/min. The load is applied gradually without shocks until the resistance of the specimen to the increasing load fails and the specimen cannot take any further load. This is noted down as the ultimate failure load. As the load is applied the crack patterns are carefully observed and studied.

The compressive strength of the sample is obtained from the following equation,

$$F_c = P/A$$

Where, F_c = Compressive strength (N/mm^2)

P = Ultimate load (N)

A = Loaded area (150 mm x 150 mm)

IV. Results and Discussions

The test results obtained for various mixes are presented below.

B. Compressive Strength after 7 Days

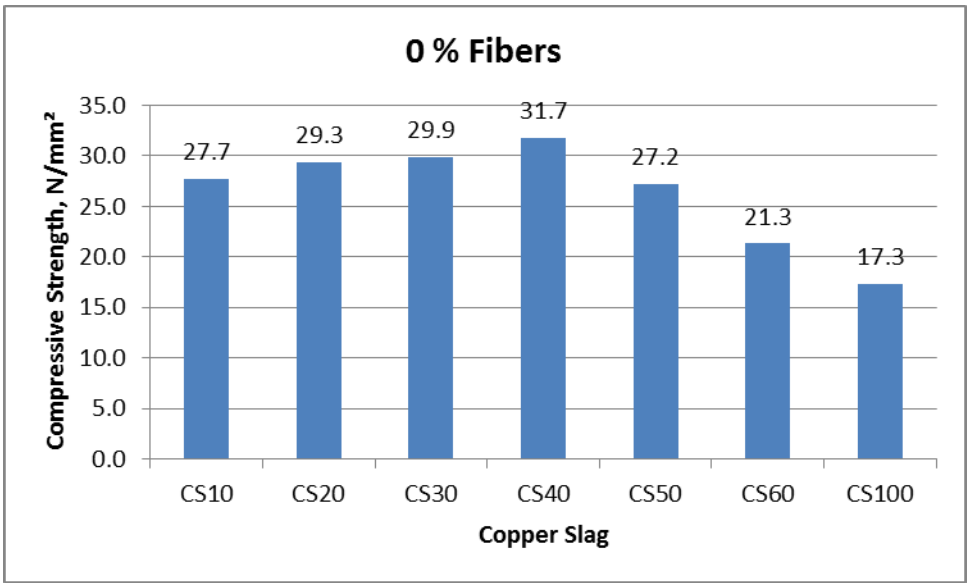
The results obtained for various percentages of polypropylene fibers and Copper Slag i.e 0%, 10%, 20%, 30%, 40%, 50%, 60% and 100% of copper slag and 0.1%, 0.2%, 0.3% and 0.4% of polypropylene after 7 days of curing are tabulated in table 1. The compressive strength for the control specimen, without copper slag and fiber and was observed to be 27.2 N/mm2 after 7 days and was observed to be 32 N/mm2 after 28 days.

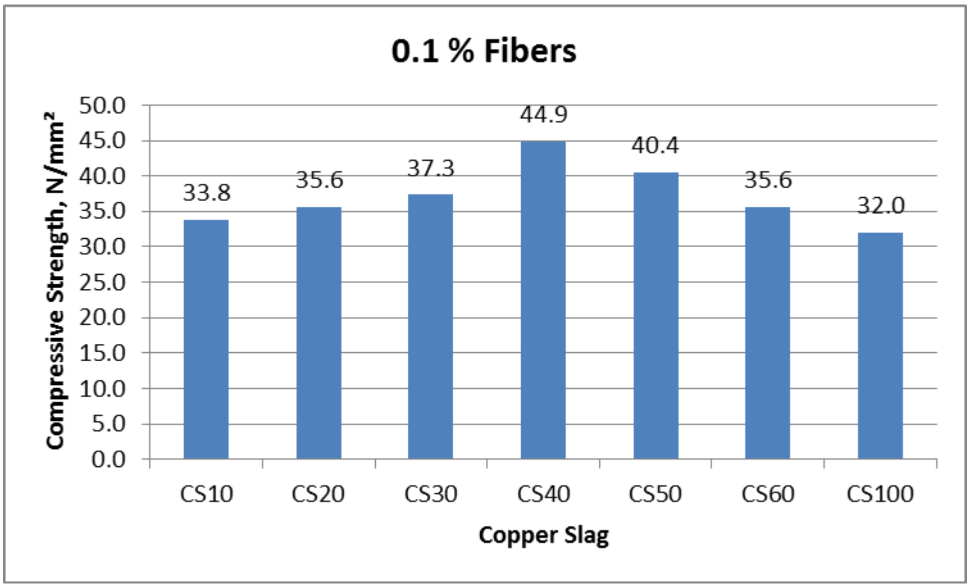
At 7 days, the compressive strength increased by 2.0%, 7.8%, 9.8%, 16.7% compared to conventional concrete when copper slag is used as replacement material by 10%, 20%, 30% and 40 % respectively. At 50% replacement there was no change and at 60% and 100% replacement, the strength decreased and was even less the conventional concrete by 21.6% and 36.3% respectively.

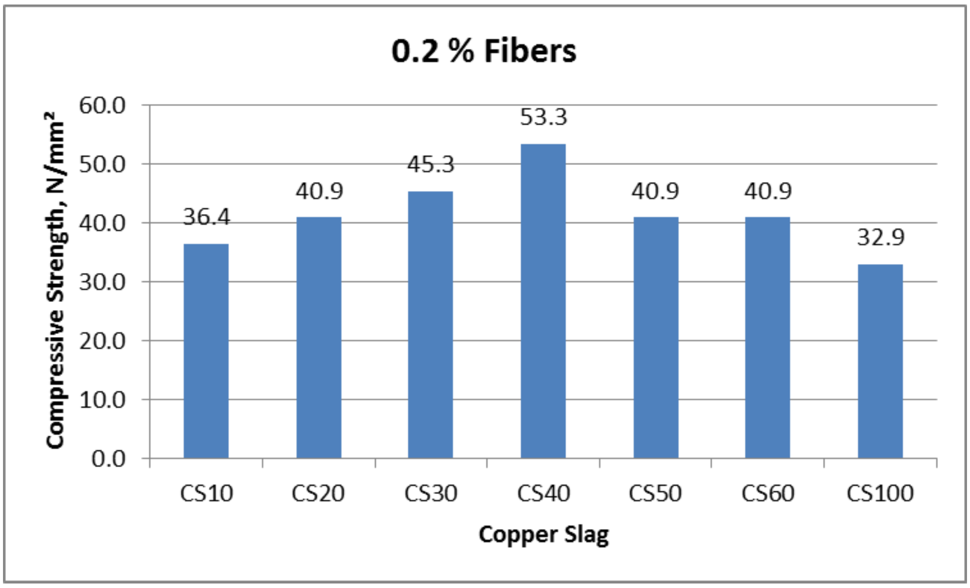
TABLE 1. 7 Days Compressive Strength, N/mm^2

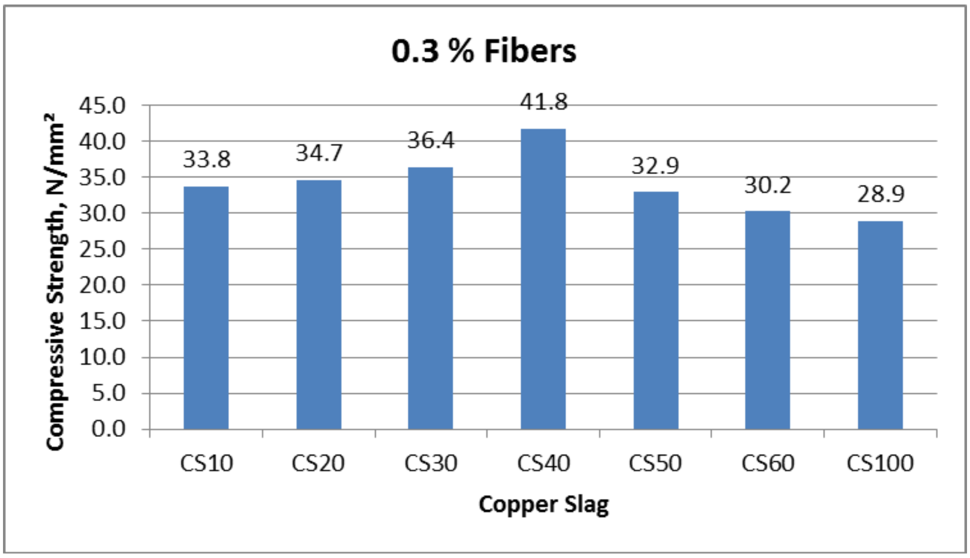
	CS10	CS20	CS30	CS40	CS50	CS60	CS100
PP0	27.7	29.3	29.9	31.7	27.2	21.3	17.3
PP0.1	33.8	35.6	37.3	44.9	40.4	35.6	32.0
PP0.2	36.4	40.9	45.3	53.3	40.9	40.9	32.9
PP0.3	33.8	34.7	36.4	41.8	32.9	30.2	28.9
pp0.4	30.2	33.3	35.1	39.1	30.2	29.3	20.0

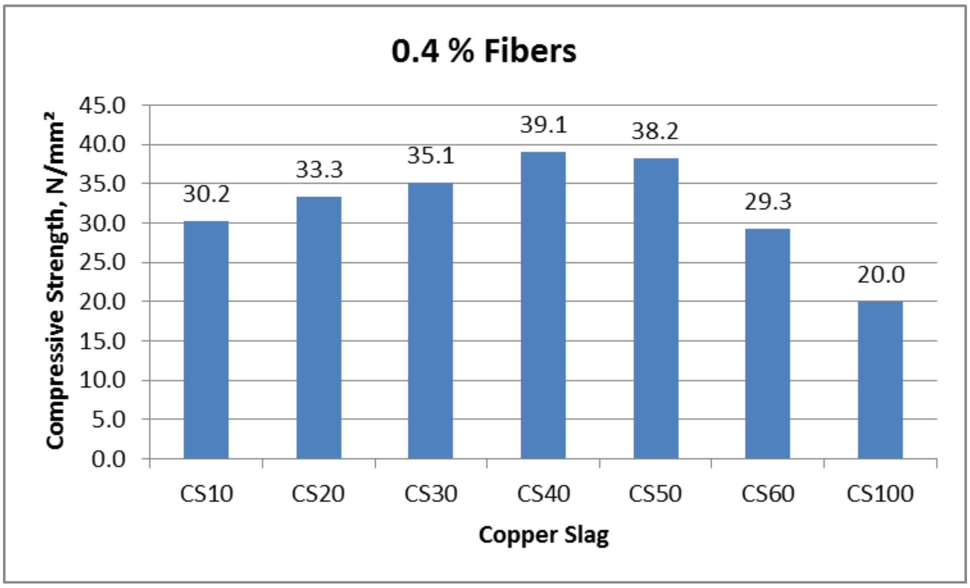
1) Effect of Copper Slag (7 Days)

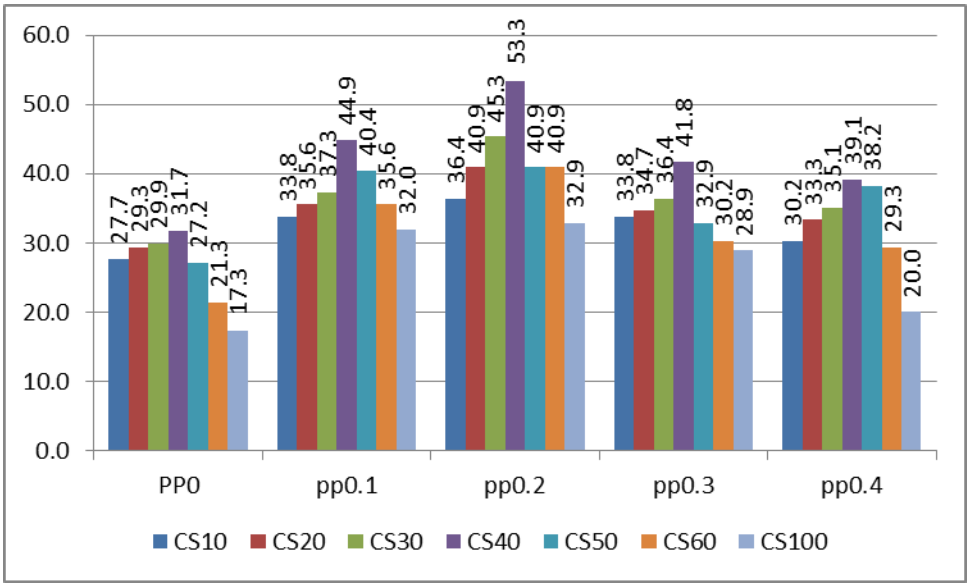




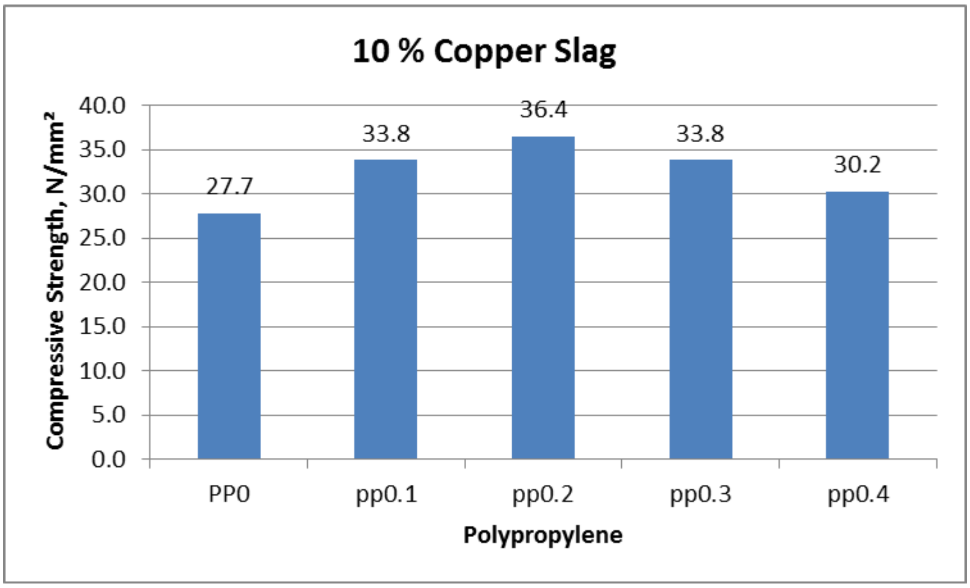

0.2 % Fibers
Compressive Strength, N/mm²
60.0
50.0
40.0
30.0
20.0
10.0
0.0
36.4
40.9
45.3
53.3
40.9
40.9
32.9
CS10
CS20
CS30
CS40
CS50
CS60
CS100
Copper Slag

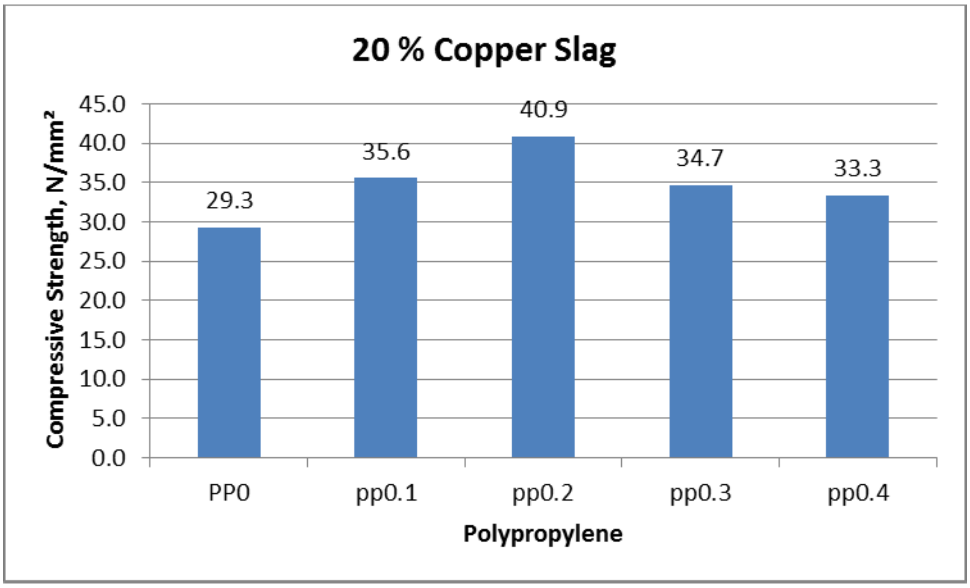

0.3 % Fibers
Compressive Strength, N/mm²
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
33.8
34.7
36.4
41.8
32.9
30.2
28.9
CS10
CS20
CS30
CS40
CS50
CS60
CS100
Copper Slag

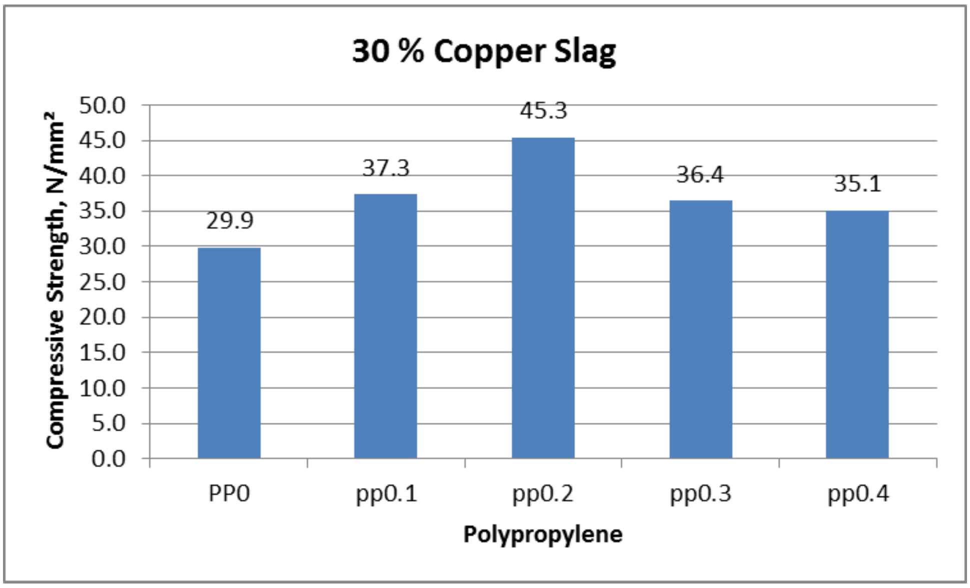

0.4 % Fibers
Compressive Strength, N/mm²
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
30.2
33.3
35.1
39.1
38.2
29.3
20.0
CS10
CS20
CS30
CS40
CS50
CS60
CS100
Copper Slag

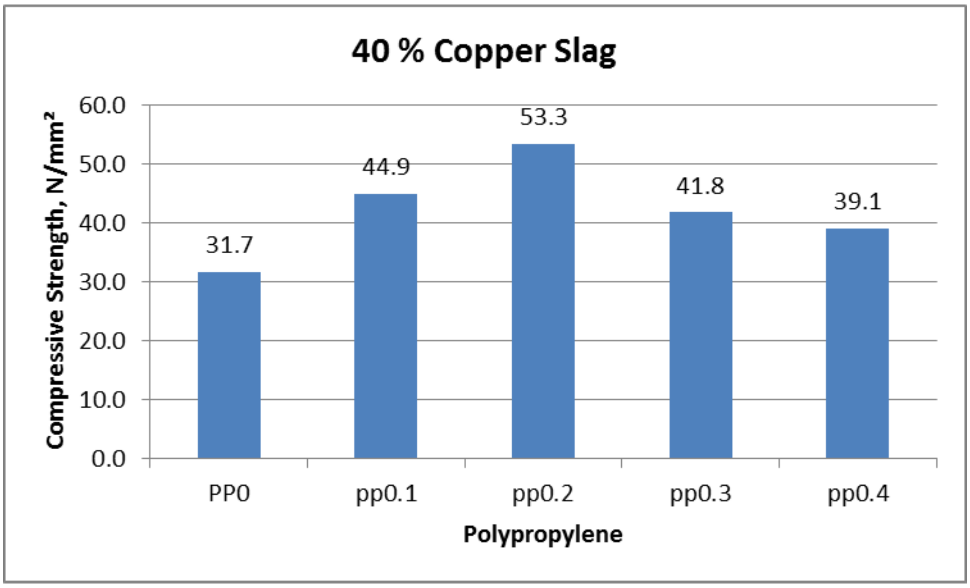


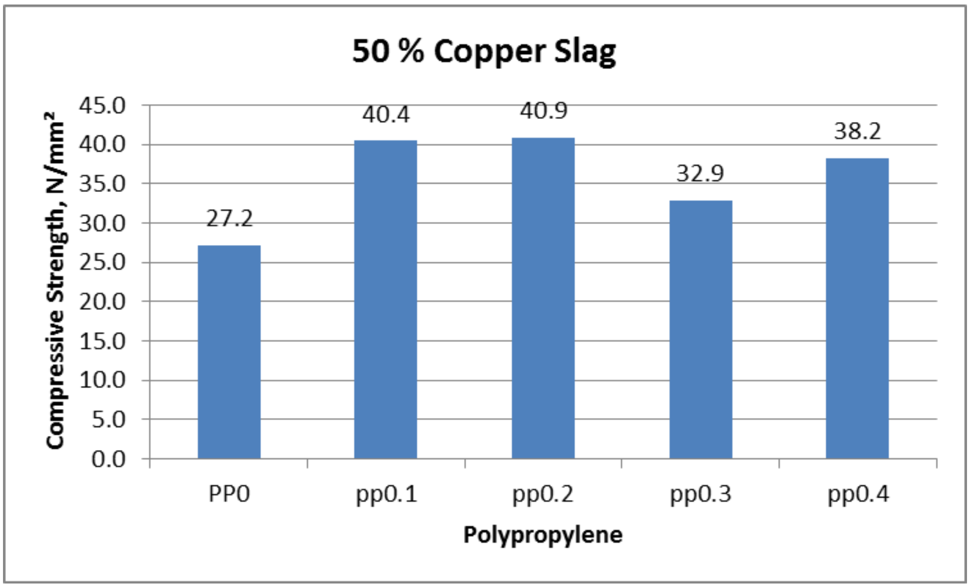
2) Effect of Fibers (7 Days)

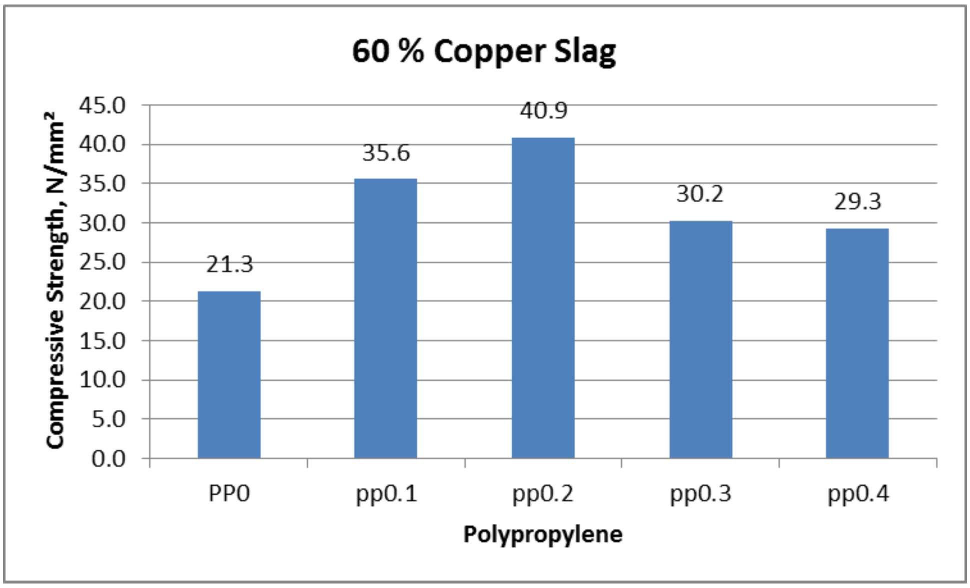


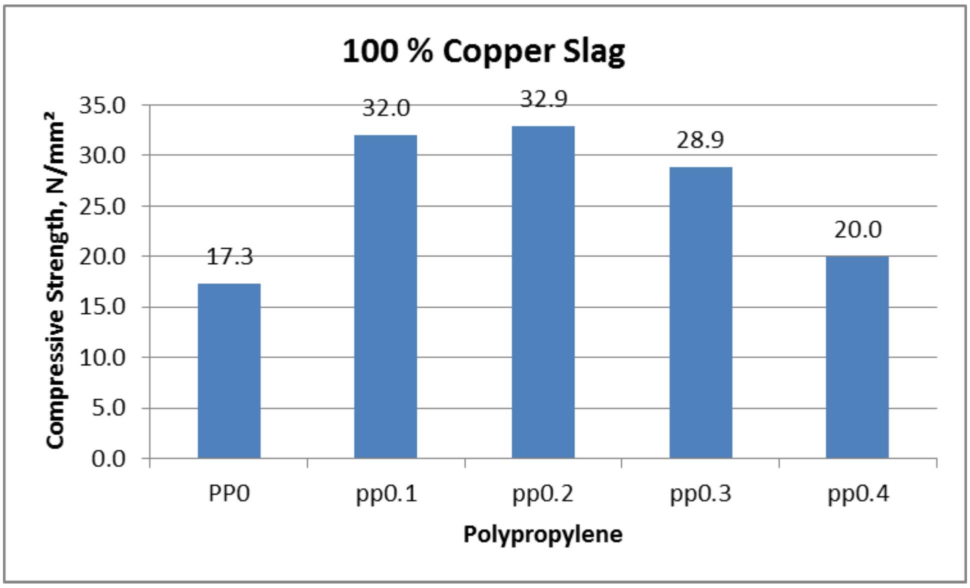



30 % Copper Slag
Compressive Strength, N/mm²
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
29.9
37.3
45.3
36.4
35.1
PP0
pp0.1
pp0.2
pp0.3
pp0.4
Polypropylene


40 % Copper Slag
Compressive Strength, N/mm²
60.0
50.0
40.0
30.0
20.0
10.0
0.0
31.7
44.9
53.3
41.8
39.1
PP0
pp0.1
pp0.2
pp0.3
pp0.4
Polypropylene


50 % Copper Slag
Compressive Strength, N/mm²
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
27.2
40.4
40.9
32.9
38.2
PP0
pp0.1
pp0.2
pp0.3
pp0.4
Polypropylene


60 % Copper Slag
Compressive Strength, N/mm²
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
21.3
35.6
40.9
30.2
29.3
PP0
pp0.1
pp0.2
pp0.3
pp0.4
Polypropylene


100 % Copper Slag
Compressive Strength, N/mm²
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
17.3
32.0
32.9
28.9
20.0
PP0
pp0.1
pp0.2
pp0.3
pp0.4
Polypropylene

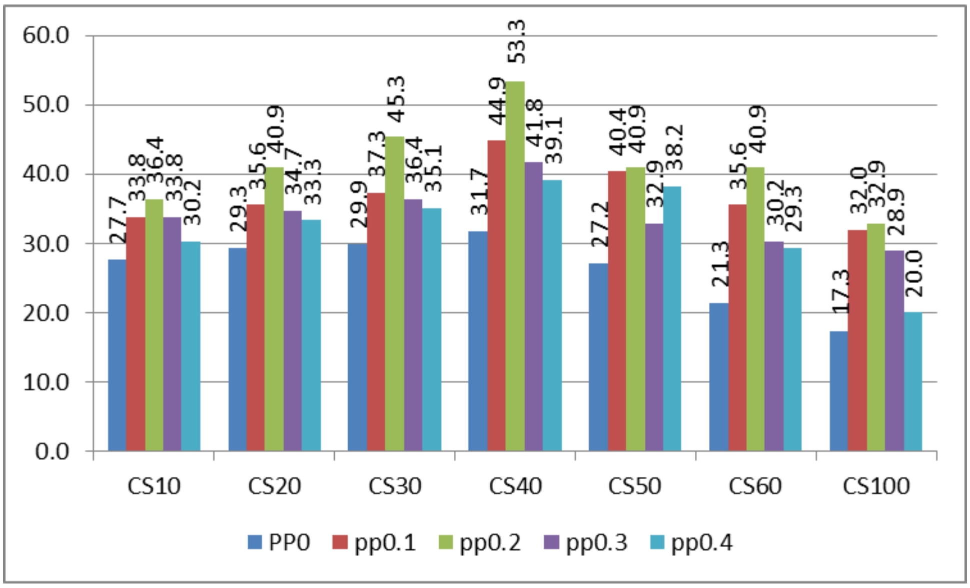

60.0
50.0
40.0
30.0
20.0
10.0
0.0
27.7 33.8 36.4 33.8 30.2
29.3 35.6 40.9 34.7 33.3
29.9 37.3 45.3 36.4 35.1
31.7 44.9 53.3 41.8 39.1
27.2 40.4 40.9 32.9 38.2
21.3 35.6 40.9 30.2 29.3
17.3 32.0 32.9 28.9 20.0
CS10
CS20
CS30
CS40
CS50
CS60
CS100
PP0
pp0.1
pp0.2
pp0.3
pp0.4

TABLE 2. Percentage increase in strength compared to conventional concrete at 7 Days

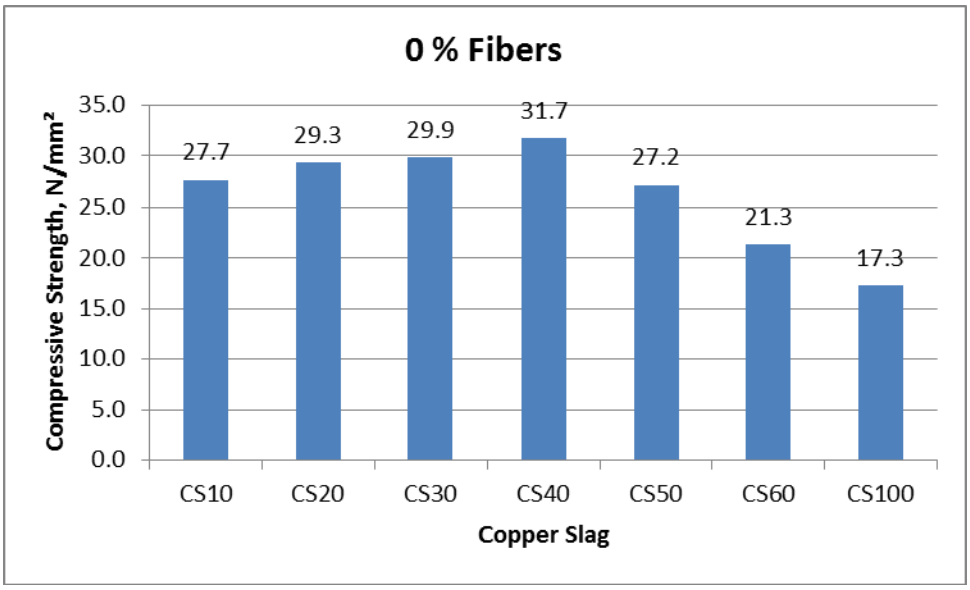
	CS10	CS20	CS30	CS40	CS50	CS60	CS100
PP0	2.0	7.8	9.8	16.7	0.0	-21.6	-36.3
pp0.1	24.2	30.7	37.3	65.0	48.7	30.7	17.6
pp0.2	34.0	50.3	66.7	96.1	50.3	50.3	20.9
pp0.3	24.2	27.5	34.0	53.6	20.9	11.1	6.2
pp0.4	11.1	22.5	29.1	43.8	40.5	7.8	-26.5

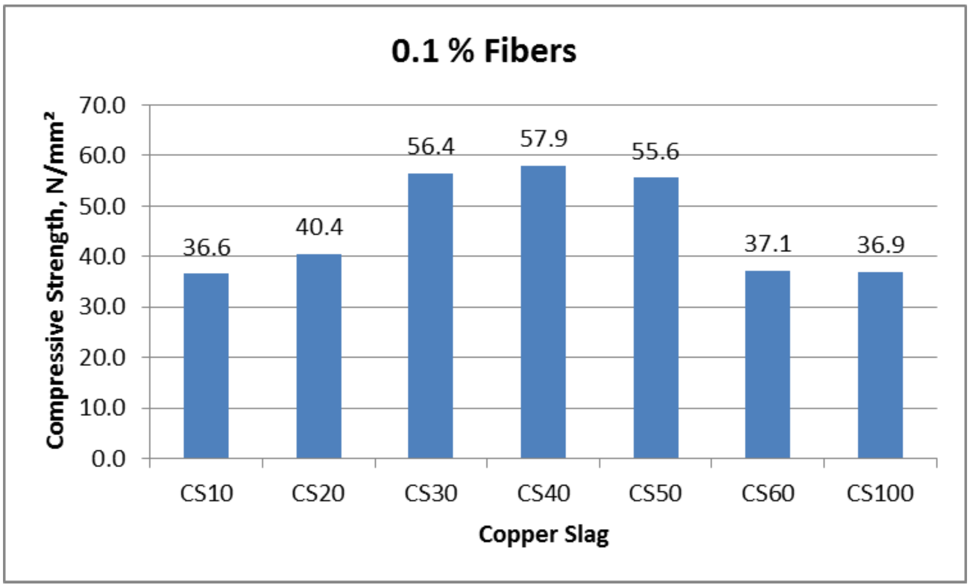
B. Compressive Strength after 28 Days

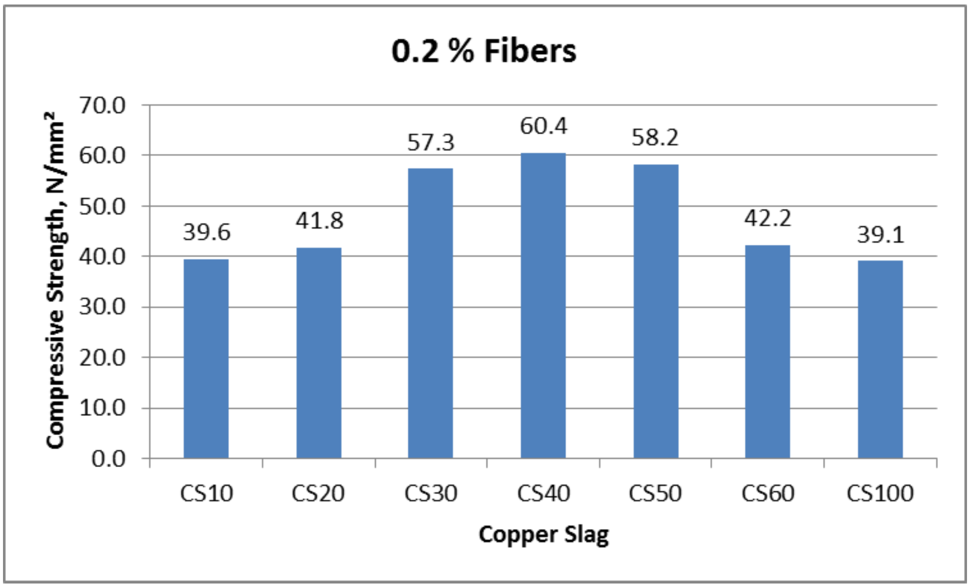
TABLE 3. 28 Days Compressive Strength, N/mm^2

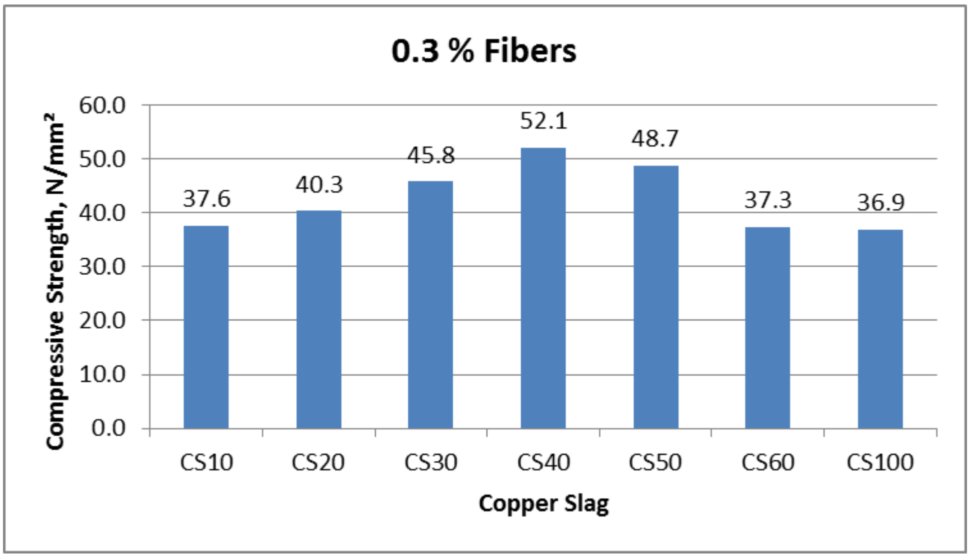
	CS0	CS10	CS20	CS30	CS40	CS50	CS60	CS100
PP0	32.0	34.4	34.9	35.4	56.9	53.3	36.4	35.6
PP0.1	-	36.6	40.4	56.4	57.9	55.6	37.1	36.9
PP0.2	-	39.6	41.8	57.3	60.4	58.2	42.2	39.1
PP0.3	-	37.6	40.3	45.8	52.1	48.7	37.3	36.9
PP0.4	-	30.7	33.8	44.9	48.0	43.6	36.4	36.0

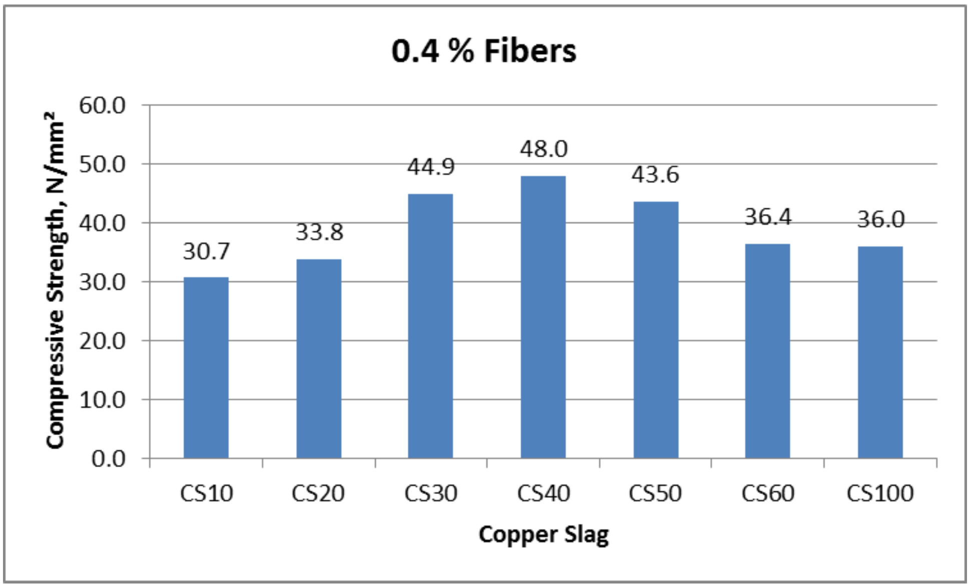
1) Effect of Copper Slag (28 Days)

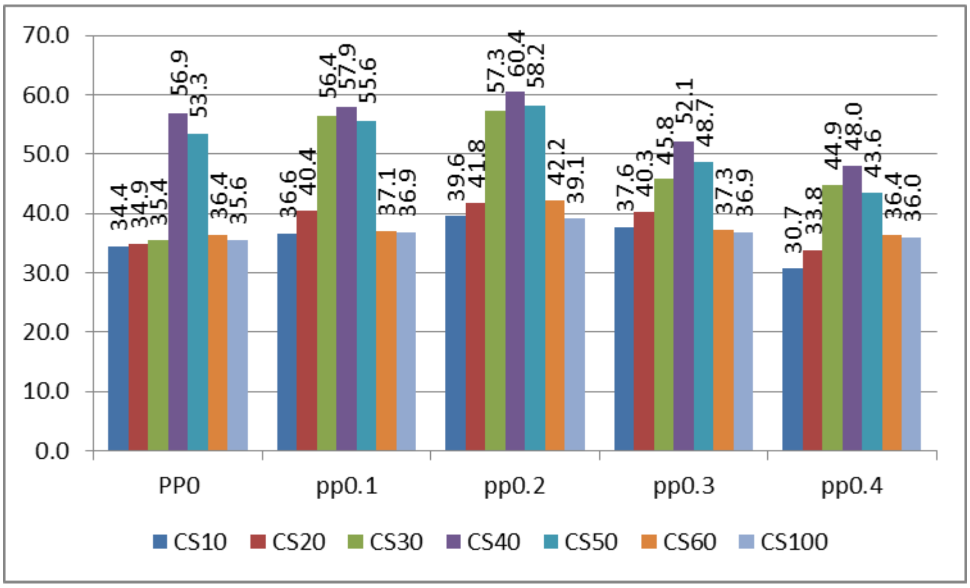



0.1 % Fibers
Compressive Strength, N/mm²
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
36.6
40.4
56.4
57.9
55.6
37.1
36.9
CS10
CS20
CS30
CS40
CS50
CS60
CS100
Copper Slag

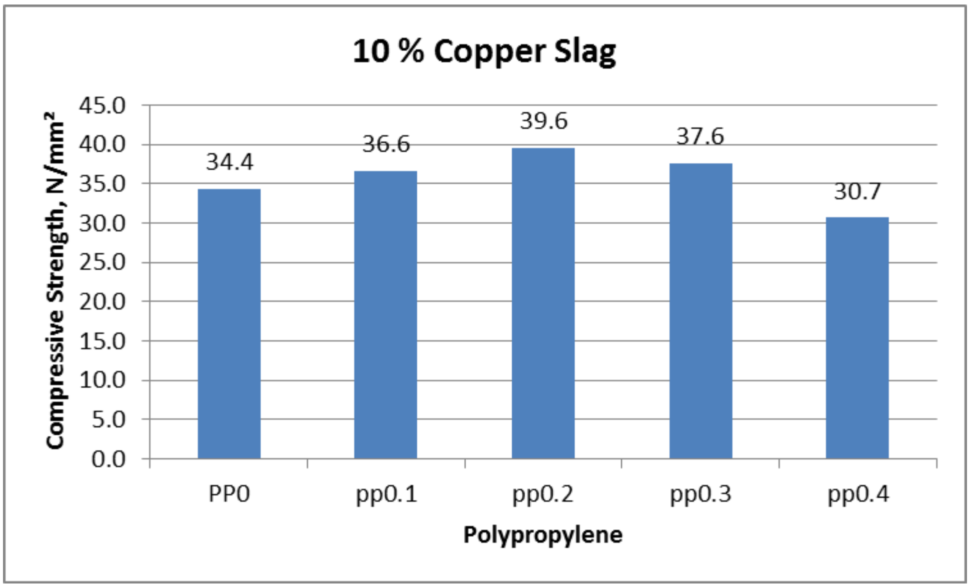

0.2 % Fibers
Compressive Strength, N/mm²
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
39.6
41.8
57.3
60.4
58.2
42.2
39.1
CS10
CS20
CS30
CS40
CS50
CS60
CS100
Copper Slag

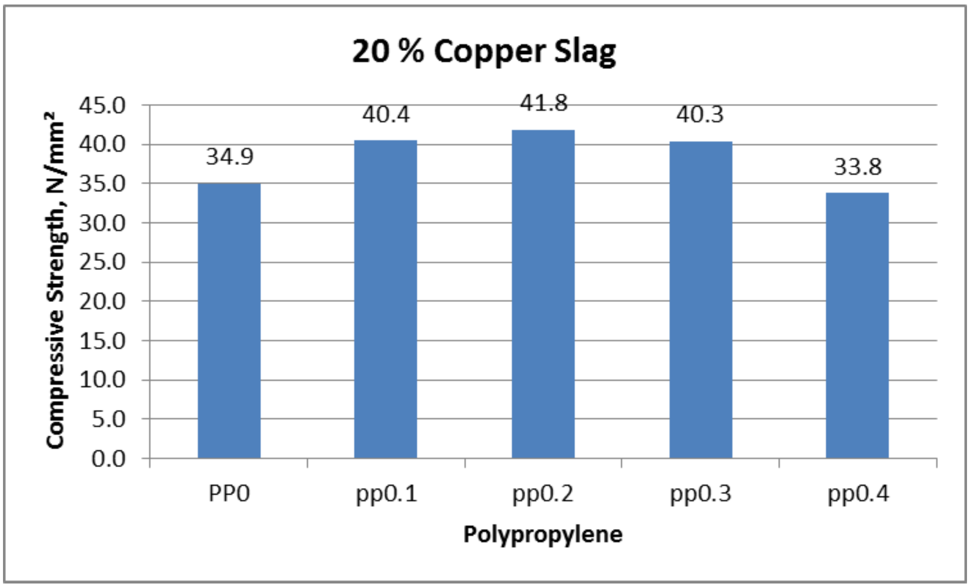

0.3 % Fibers
Compressive Strength, N/mm²
60.0
50.0
40.0
30.0
20.0
10.0
0.0
37.6
40.3
45.8
52.1
48.7
37.3
36.9
CS10
CS20
CS30
CS40
CS50
CS60
CS100
Copper Slag

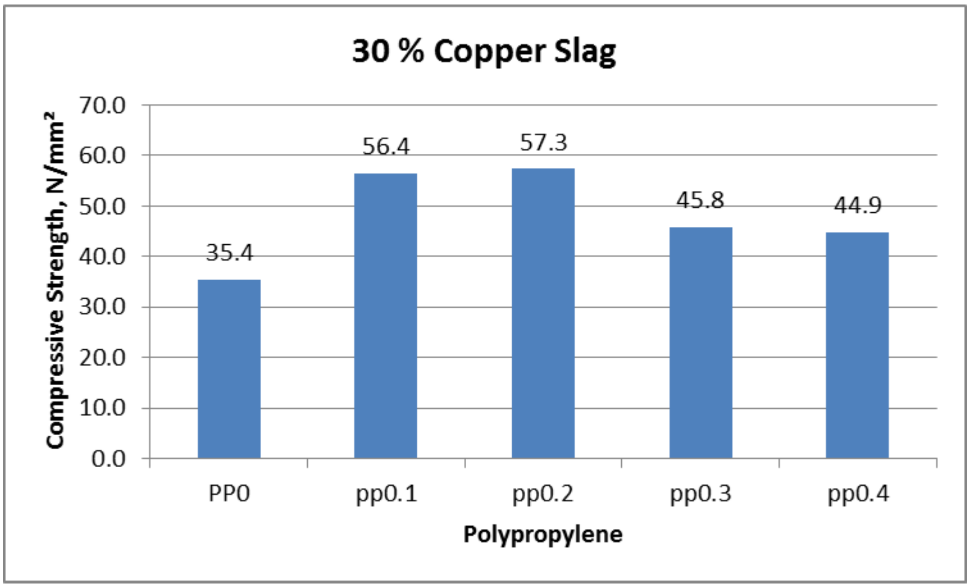


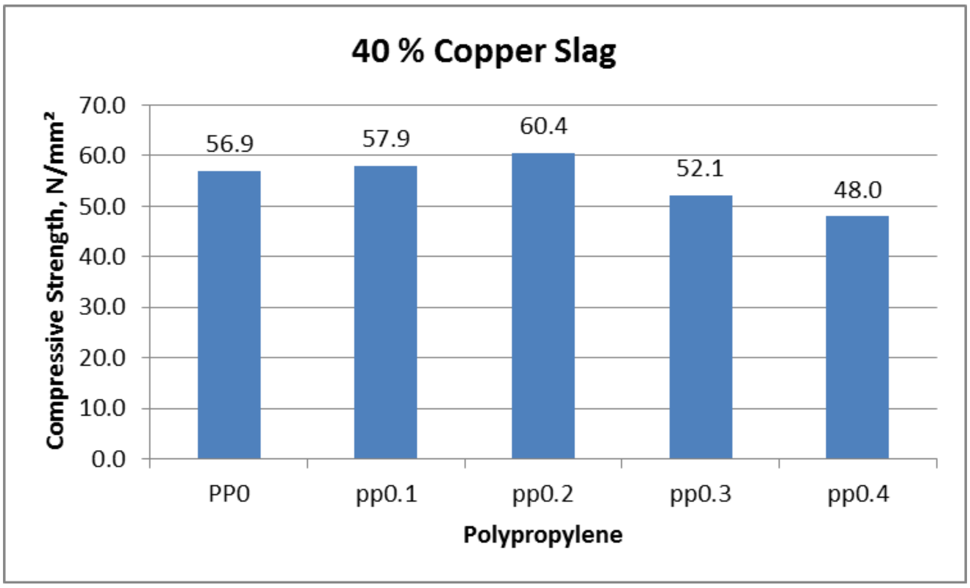


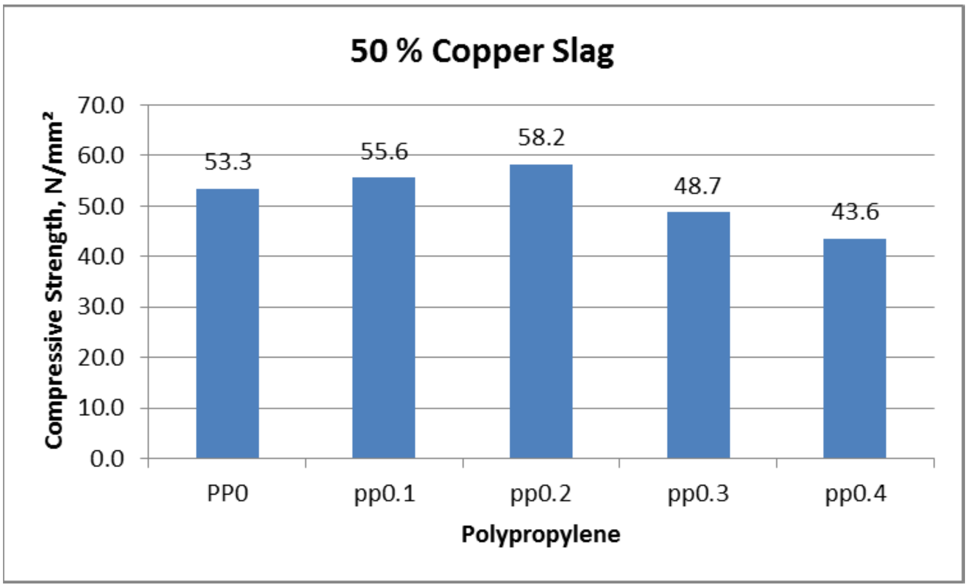
2) *Effect of Fibers (28 Days)*

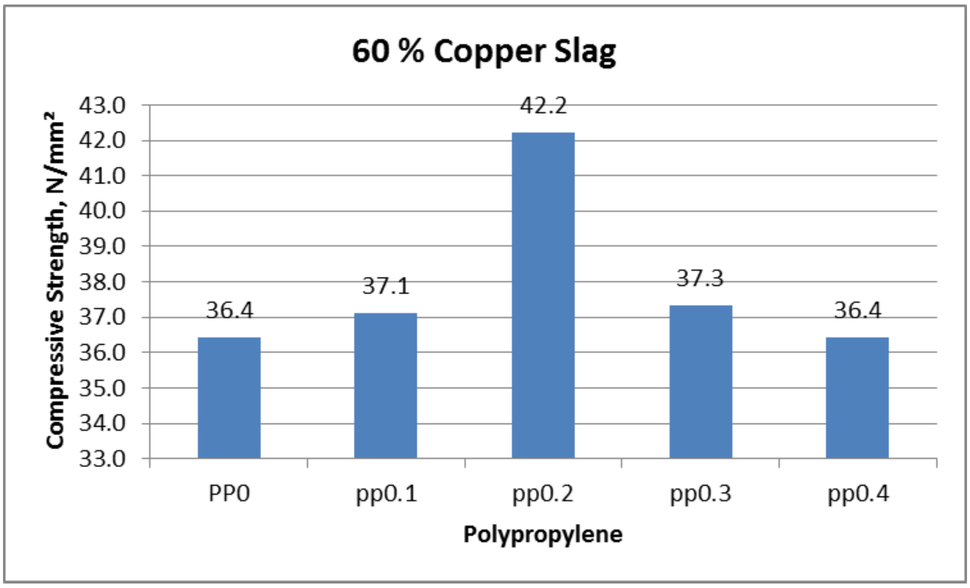


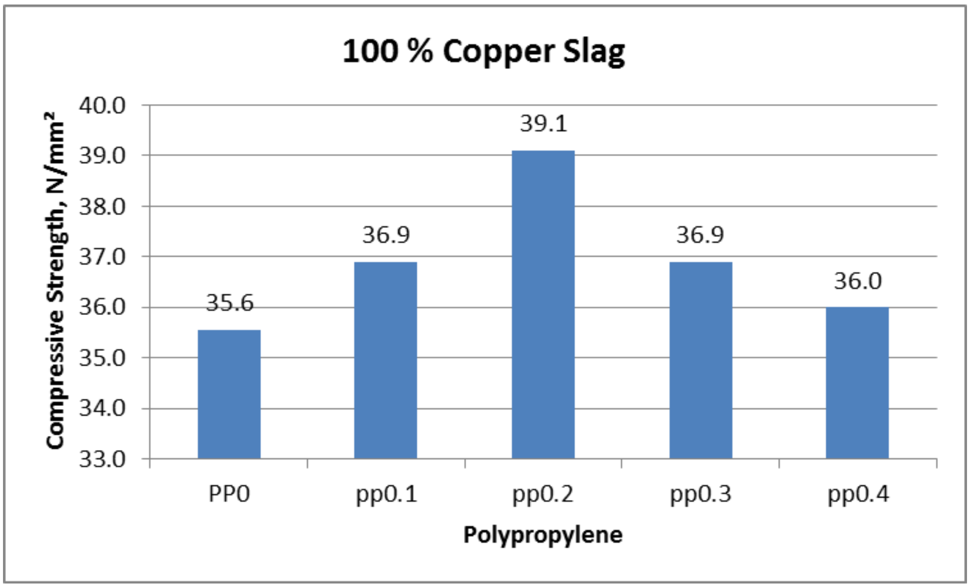

20 % Copper Slag
Compressive Strength, N/mm²
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
34.9
40.4
41.8
40.3
33.8
PP0
pp0.1
pp0.2
pp0.3
pp0.4
Polypropylene


30 % Copper Slag
Compressive Strength, N/mm²
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
35.4
56.4
57.3
45.8
44.9
PP0
pp0.1
pp0.2
pp0.3
pp0.4
Polypropylene


40 % Copper Slag
Compressive Strength, N/mm²
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
56.9
57.9
60.4
52.1
48.0
PP0
pp0.1
pp0.2
pp0.3
pp0.4
Polypropylene


50 % Copper Slag
Compressive Strength, N/mm²
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
53.3
55.6
58.2
48.7
43.6
PP0
pp0.1
pp0.2
pp0.3
pp0.4
Polypropylene


60 % Copper Slag
Compressive Strength, N/mm²
43.0
42.0
41.0
40.0
39.0
38.0
37.0
36.0
35.0
34.0
33.0
36.4
37.1
42.2
37.3
36.4
PP0
pp0.1
pp0.2
pp0.3
pp0.4
Polypropylene


100 % Copper Slag
Compressive Strength, N/mm²
40.0
39.0
38.0
37.0
36.0
35.0
34.0
33.0
35.6
36.9
39.1
36.9
36.0
PP0
pp0.1
pp0.2
pp0.3
pp0.4
Polypropylene

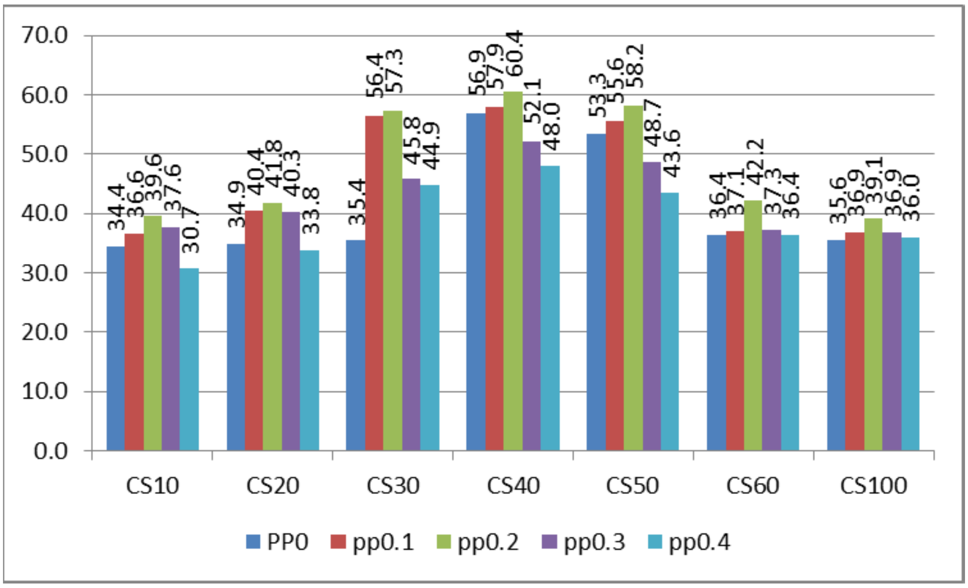


TABLE 4. Percentage increase in strength compared to conventional concrete at 28 Days

	CS10	**CS20**	**CS30**	**CS40**	**CS50**	**CS60**	**CS100**
PP0	7.5	9.2	10.7	77.8	66.7	13.9	11.1
pp0.1	14.3	26.4	76.4	81.0	73.6	16.0	15.3
pp0.2	23.6	30.6	79.2	88.9	81.9	31.9	22.2
pp0.3	17.6	26.0	43.1	62.9	52.2	16.7	15.3
pp0.4	-4.2	5.6	40.3	50.0	36.1	13.9	12.5

After 28 days, it is interestingly observed that the compressive strength was in no case less than the conventional concrete. Even with 100% replacement of sand with copper slag, there was still an increase of 11.1% in the compressive strength compared to concrete with 100% sand as fine aggregate. The compressive strength increased by 7.5%, 9.2%,10.7%, 77.8%, 66.7% and 13.9% for copper slag content of 10%, 20%, 30%, 40%, 50% and 60% respectively.

From the tables and graphs it is evident that the compressive strength increases upto 40% of copper slag content both at 7 days and 28 days and with further replacement, the strength decreases. With regard to the addition of fibers, it can be concluded that addition of fibers till 0.2% by volume is acceptable. Beyond this the strength is reduced. During the early age of 7 days, the strength increased by 96% for concrete with 40% copper slag and 0.2% fibers when compare to conventional concrete. After 28 days the increase in strength is observed to be 89% for concrete with 40% copper slag and 0.2% fibers. Hence it is advisable to use 40% copper slag and 0.2% polypropylene fibers beyond which the desired strength may not be achieved.

V. Conclusions

From the experimental investigations conducted, the following are the conclusions drawn.

1. Copper slag is a suitable material for replacement of fine aggregate in concrete.
2. Copper slag concrete with addition of polypropylene fibers showed considerable increase in strength when used with in permissible quantities.
3. The maximum strength was achieved for 40 % replacement of fine aggregate with copper slag. Further addition of copper slag reduces the strength.
4. The optimum fiber content is 0.2%. It is not advisable to add fibers beyond 0.2% as excessing fiber content causes balling effect and hence reduction in strength.
5. It can be concluded that 40% of copper slag with 0.2% of polypropylene content is the most optimum value.

Acknowledgment

The authors would like to thank the Management and the Research Section, SRM University for supporting this work and encouraging us to carry out the research.

REFERENCES

[1] Alnuaimi, "Effects of Copper Slag as a Replacement for Fine Aggregate on the Behavior and Ultimate Strength of Reinforced Concrete Slender Columns", TJER, Vol. 9, No. 2, 90-102, 2012.

[2] Bipra gorai, R.K. Jana, Premchand, "Characteristics and utilisation of copper slag - a review". Resources, Conservation and Recycling, 39, pp.299-313, 2013.

[3] Antonio M. Arino and Barzin Mobasher, "Effect of Ground Copper Slag on Strength and Toughness of Cementitious Mixes", ACI Materials Journal ,V.96, No.1, pp.68-74, 1999.

[4] Binaya Patnaik, Seshadri, Sekhar.T and Srinivasa Rao, "An Experimental Investigation on Optimum Usage of Copper Slag as Fine Aggregate in Copper Slag Admixed Concrete" International Journal of Current Engineering and Technology, Vol.4, No.5, Oct 2014.

[5] B. Mobasher M, R. Devaguptapu , A.M.Arino, "Effect Of Copper Slag on the Hydration of Blended Cementitious Mixtures" Proceedings, ASCE, Materials Engineering Conference, Materials for the New Millenium, ed. K. Chong, pp. 1677-86, 1996.

[6] Caijun Shi, Christian Meyer, Ali Behnood "Utilization of copper slag in cement and concrete" Resources, Conservation and Recycling, 52, pp 1115–1120, 2008.

[7] D.Brindha,Baskaran.T, Nagan.S, "Assessment of Corrosion and Durability Characteristics of Copper Slag Admixed Concrete" International Journal Of Civil And Structural Engineering Volume 1, No 2, 2010.