Experimental Study On Compressive Strength And Drying Shrinkage Of Concrete With Copper Slag As Replacement For Fine Aggregate

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ABSTRACT

This project reports on compressive strength and drying shrinkage of concrete an experimental program to investigate the effect copper slag and polypropylene fibre. Copper slag is used as material for replacement of fine aggregate in concrete and polypropylene used an additive in the concrete. In this work, concrete grade M30 was used and IS method was used for mix design. The properties of material for cement, fine aggregates, coarse aggregates and copper slag were obtained by material testing and mix design. The compressive strength and drying shrinkage was studied for various replacements of fine aggregate by copper slag in proportions of 0%, 10%, 20%, 30%, 40%, 50%, 60% and 100%. The polypropylene fiber was varied from 0.1%, 0.2%, 0.3%, and 0.4% by weight of concrete. The test was carried out to obtain a characteristic strength of $30N/mm^2$.The compressive strength was obtained at 7 and 28 days. Tests were performed for shrinkage which was determined at 7, 14 days and 28 days. As the age of concrete increased the shrinkage increased. Also with increase in copper slag content the drying shrinkage increased. The maximum compressive strength of concrete was attained 40% replacement of fine aggregates at 7 and 28 days. When 0.2% of polypropylene was added maximum compressive strength was obtained.

INTRODUCTION

1.1 General

Concrete is the most widely used man-made construction materials in the world. Slightly more than a ton of concrete is produced each year for every human being on the planet fundamentally, concrete is economical, strong, and durable. Although concrete technology across the industry continues to rise to the demands of a changing market place. The construction industry recognizes that considerable improvements are essential in productivity, product performance, energy efficiency and environmental performance. The industry will need to face and overcome a number of institutional competitive and technical challenges. One of the major challenges with the environmental awareness and scarcity of space for land-filling is the wastes/by-products utilization as an alternative to disposal. Throughout the industrial sector, including the concrete industry, the cost of environmental compliance is high. Use of industrial by-products such as foundry sand, fly ash, bottom ash and slag can result in significant improvements in overall industry energy efficiency and environmental performance.

The consumption of all type of aggregates has been increasing in recent years in most countries at a rate far exceeding that suggested by the growth rate of their economy or of their construction industries. Artificially manufactured aggregates are more expensive to produce, and the available source of natural aggregates may be at a considerable distance from the point of use, in which case, the cost of transporting is a disadvantage. The other factors to be considered are the continued and expanding extraction of natural aggregates accompanied by serious environmental problems. Often it leads to irremediable deterioration of the country side. Quarrying of aggregates leads to disturbed surface area etc., but the aggregates from industrial wastes are not only adding extra aggregate sources to the natural and artificial aggregate but also prevent environmental pollution.

1.2 Copper Slag

Copper slag is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial or full substitute of either cement or aggregates. It is a by-product obtained during the matte smelting and refining of copper. To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material. In Oman approximately 60,000 tons of copper slag is produced every year (Alnuaimi AS et al., 2012). Copper slag is a by-product material produced from the process of manufacturing copper. As the copper settles down in the smelter, it has a higher density, impurities stay in the top layer and then are transported to a water basin with a low temperature for solidification. The end product is a solid, hard material that goes to the crusher for further processing.

For every tone of metal production, about 2.2 ton of waste slag is generated. Dumping or disposal of such huge quantities of slag cause environmental and space problems. During the past two decades, attempts have been made by several investigators and copper producing units all over the world to explore the possible utilization of copper slag. The physical and mechanical properties of granulated copper slag shows that it can be used to make products like coarse and fine aggregates, cement, fill, ballast, roofing granules, glass, tiles etc.

Copper slag abrasive is suitable for blast cleaning of steel and stone/concrete surfaces, removal of mill scale, rust, old paint, dirt etc. Blasting the grit at the surface is the most advanced approach for metal surface cleaning before paint spraying. The blasting media manufactured from copper slag brings less harm to people and environment than sand. The product meets the most rigid health and ecological standards.

Fig 1.1 Copper Slag

1.2.1 Physical Properties of Copper Slag

The slag is a black glassy and granular in nature and has a similar particle size range like sand which indicates that it could be tried as replacement for the sand in cementitious mixture. The specific gravity of the slag is 3.68. The bulk density of granulated copper slag is varying between 1.70 to 1.90 g/cc which is almost similar to the bulk density of conventional fine aggregate. The hardness of the slag lies between 6 and 7 in MoH scale. This is almost equal to the hardness of gypsum. The pH of aqueous solution of aqueous extract as per IS 11127 varies from 6.6 to 7.2. The limiting water soluble chloride content as per IS 11127 is 11ppm. The slag is conforming to the above standards. The free moisture content present in slag was found to be less than 1%. The sieve analysis for copper slag infers that the gradation properties of fine aggregates at all the replacement levels are similar to the specification for sand zone II as per IS: 383

Table 1.1 Physical properties of copper

Sl. No.	Characteristic	Unit
1	Hardness	7(Moh's Scale)
2	Specific Gravity	3.83
3	Electric Conductivity	4.8mS/m

4	Chloride Content	<0.0002
5	Granule Shape	Angular, sharp edges & multifaceted
6	Particle Size	0.2mm to 3.00mm
7	Solubility	Insoluble

1.2.2 Chemical Properties of Copper Slag

The chemical composition of slag is presented in Table .1. The presence of silica in slag is about 26% which is desirable since it is one of the constituents of the natural fine aggregate used to normal concreting operations. The presence of copper, alumina, sulphate in the slag were only traces and hence not harmful.

Table 1.2 Chemical properties of copper

Sl. No.	Chemical Compounds	% of Compounds
1	Fe_2O_3	68.29
2	SiO_2	25.84
3	Al_2O_3	0.22
4	CaO	0.15
5	MgO	0.2
6	Na_2O	0.58
7	K_2O	0.23
8	Mn_2O_3	0.22

1.2.3 Uses of Copper Slag

- Copper slag has also gained popularity in the building industry for use as a fill material.
- Contractors may also use copper slag in place of sand during concrete construction.
- Copper slag can also be used as a building material, formed into blocks.
- Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools.
- Copper slag is widely used as an abrasive media to remove rust, old coating and other impurities in dry abrasive blasting due to its high hardness (6-7 Mohs), high density (2.8-3.8 g/cm3) and low free silica content.

Fig 1.2 Slag Blasting

1.3 Polypropylene

- Name of the fibre ENDURO HPP45.
- ENDURO HPP45 is a non synthetic fibre designed specially

for the reinforcement of concrete and other cementitious mixes.

Fig.1.3 Polypropylene

- It serves to effectively anchor the fibres into the concrete thus resisting matrix pull-out and enhancing the concretes performance even after it has developed stress cracks.
- Important feature of this design is that it allows much higher dosage levels resulting in performance levels which extend beyond those achieved with traditional secondary reinforcement.

Polypropylene (PP), also known as polypropene, is a thermoplastic polymer used in a wide variety of applications including packaging and labeling, textiles (e.g., ropes, thermal underwear and carpets), stationery, plastic parts and reusable containers of various types, laboratory equipment, loudspeakers, automotive components, and polymer banknotes. An addition polymer made from the monomer propylene, it is rugged and unusually resistant to many chemical solvents, bases and acids. In 2013, the global market for polypropylene had a volume of about 55 million metric tons.

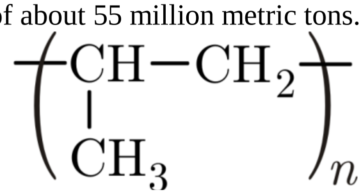


Fig.1.4 Structure of a polypropylene in general

In concrete, it serves to effectively anchor the fibers thus resisting matrix pull-out and enhancing the concretes performance even after it has developed stress cracks. Important feature of this design is that it allows much higher dosage levels resulting in performance levels which extend beyond those achieved with traditional secondary reinforcement. In this project Polypropylene have used ENDURO HPP45

1.3.1 Features and Benefits

1. Increase flexural stiffness
2. Increase cohesion and decrease segregation
3. Non magnetic
4. Rust proof
5. Increases impact and shatter resistance
6. Safe and easy to handle
7. Economical alternative for steel fibers

1.3.2 Chemical and Physical Properties of ENDURO HPP45

1. Fiber Length- 45mm
2. Acid and Salt resistance- High
3. Type/Shape- Macro/Monofilament
4. Absorption- Nil
5. Specific Gravity- 0.91
6. Electrical Conductivity- Low
7. Melt Point- 164ºC
8. Ignition Point- >550ºC
9. Thermal Conductivity- Low
10. Alkali Resistance- Alkali Proof

1.3.3 Primary Applications

1. Ground Supported Slabs
2. External Pavements
3. Roads
4. Precast and Airport Pavements
5. Overlays and Toppings

1.5 Objective of the project

To investigate the compressive strength and drying shrinkage of concrete on 7th and 28th day containing Polypropylene fiber of volume fractions of 0%,0.1%,0.2%,0.3% & 0.4% for concrete mixes with copper slag replacement with fine aggregate in ratio of 0%, 10%, 20%, 30%, 40%,50%, 60% and 100% .

1.6 Scope of the project

This project relates the replacement of Fine Aggregate in concrete. And it can be used as an alternate for Fine Aggregate in concrete. ... r we can increase its ... gth. However, the determination of compressive strength of concrete is necessary to determine the load at which the concrete members may crack.

COMPRESSIVE STRENGTH

6.1 General

For each mix proportions of concrete, standard cubes of size 150x150x150 mm were cast and tested as per IS: 516-1959 after 7 and 28 days of curing to determine the compressive strength of concrete in Compressive testing machine as in Fig 6.1

Fig 6.1 Compression testing of samples

6.2 Compressive Test Procedure

Specimens stored in water shall be tested immediately on removal from the water and while they are still in the wet condition. Surface water and grit shall be wiped off the specimens and any projecting find removed specimens when received dry shall be kept in water for 2 hours before they are taken for testing. The dimensions of the specimens to the nearest 0.2mm and their weight shall be noted before testing. Placing the specimen in the testing machine the bearing surface of the testing machine shall be wiped clean and any loose sand or other material removed from the surface of the specimen, which are to be in contact with the compression platens. In the case of cubes, the specimen shall be placed in the machine in such a manner that the load shall be applied to opposite sides of the cubes as cast, that is, not to the top and bottom. The axis of the specimen shall be carefully aligned with the centre of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine. As the spherically seated block is brought to bear on the specimen the movable portion shall be rotated gently by hand so that uniform seating may be obtained .The load shall be applied without shock and increased continuously at a rate of approximately 40 kg/min until the resistance of the specimen to the increasing load breaks down and no greater load can be appearance of the concrete and any unusual features in the type of failure shall be noted

The compressive strength of the sample can thus be given by this formula,

$$F_c = P/A$$

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

P = ultimate load (N)

A = loaded area (150 mm x 150 mm)

6.3. Compressive Strength after 7 Days

The measured compressive strength values are presented in following Tables. The results obtained for various percentages of

	CS0	CS10	CS20	CS30	CS40	CS50	CS60	CS100
PP0	612	624	660	672	714	612	480	390
pp0.1	-	760	800	840	1010	910	800	720
pp0.2	-	820	920	1020	1200	920	920	740
pp0.3	-	760	780	820	940	740	680	650
pp0.4	-	680	750	790	880	680	660	450

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%0.4% of polypropylene are tabulated. Based on the test results, graphs are plotted

Table 6.1 Compressive Strength – Ultimate Loads (kN) after 7 daysTable 6.2 Compressive Strength (N/mm^2) after 7 days

6.3.1 Effect of Copper Slag

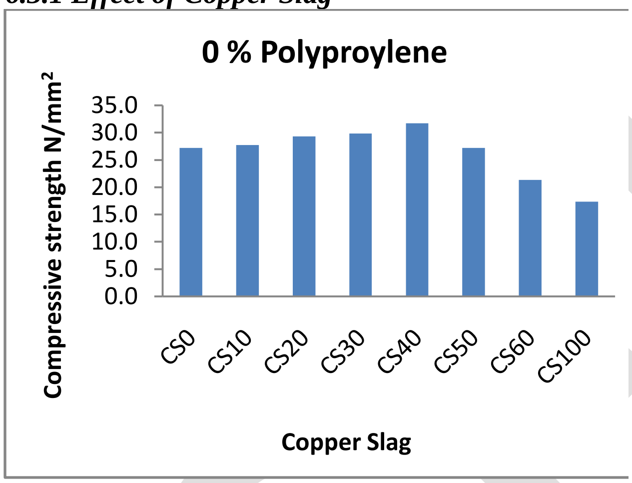


Fig 6.2 Compressive Strength for 0%Polypropylene

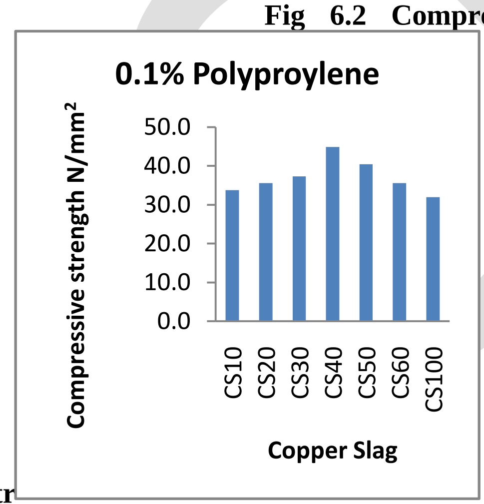


Fig 6.3 Compressive Strength for 0.1%Polypropylene

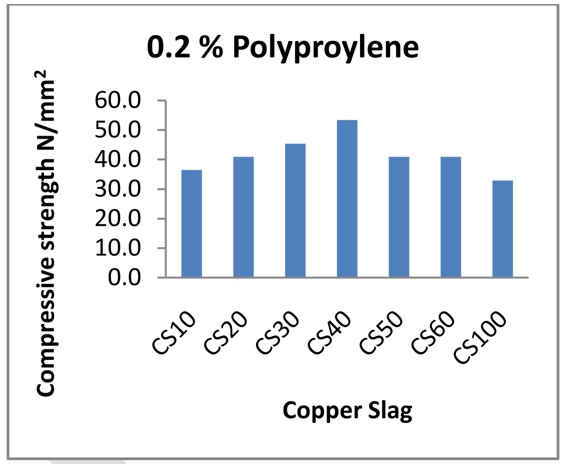


Fig 6.4 Compressive Strength for 0.2%Polypropylene

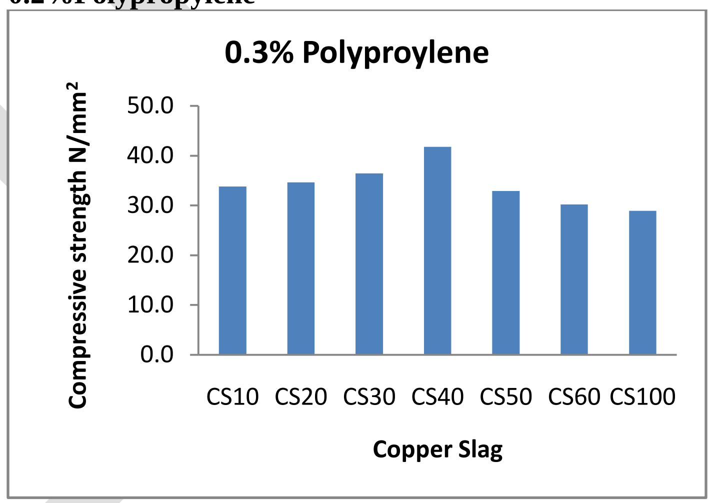


Fig 6.5 Compressive Strength for 0.3%Polypropylene

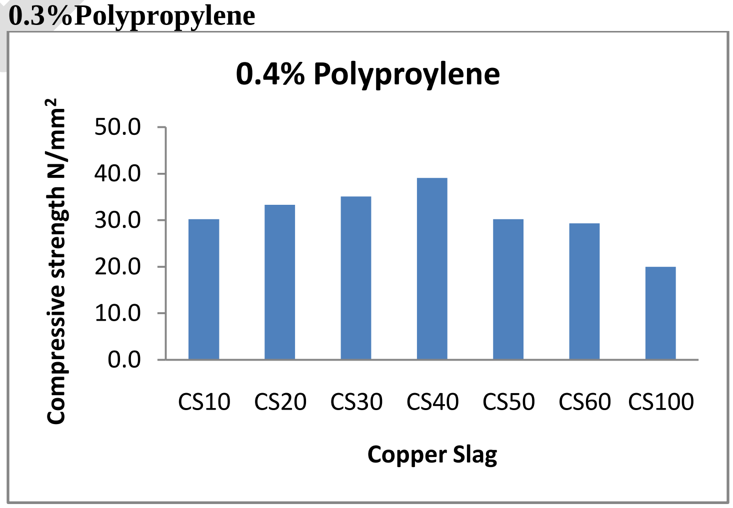


Fig 6.6 Compressive Strength for 0.4%Polypropylene

Effect of Copper Slag

i. **For 0.1% Polypropylene**

The compressive strength increases by 65% for 40% replacement of copper slag. The increase in compressive strength was 24.2%, 30.7%, 37.3% and 65% for 10%, 20%, 30%, and 40% for copper slag respectively. The strength decreased beyond this. However strength increased by 17.6%. When the copper slag content is increased to 100% replacement of copper slag when compared to control mix

ii. **For 0..2% Polypropylene**

The compressive strength increases by 96% for 40% replacement of copper slag. The increase compressive strength was 34%, 50.3%, 66.7% and 96% for 10%, 20%, 30%, and 40% for copper slag content. The strength decreased beyond this. However strength increased by 20.9%. When the copper slag content is increased to 100% replacement of copper slag when compared to control mix

iii. **For 0.3% Polypropylene**

The compressive strength increases by 57.6 for 40% replacement of copper slag. The increase compressive strength was 24.2%, 27.5%, 34% and 96% for 10%, 20%, 30%, and 40% for copper slag content. The strength decreased beyond this. However strength increased by 6.2%. When the copper slag content is increased to 100% replacement of copper slag when compared to control mix

iv. **For 0.4% Polypropylene**

The compressive strength increases by 43.8 for 40% replacement of copper slag. The increase compressive strength was 11.1%, 22.5%, 29.1% and 43.8% for 10%, 20%, 30%, and 40% for copper slag content. The strength decreased beyond this. However strength increased by 6.2% when the copper slag content is increased to 60% when compared to control mix. But when the copper slag content is 100% the strength decreased by 26.5% in this case

6.3.2 Effect of Polypropylene

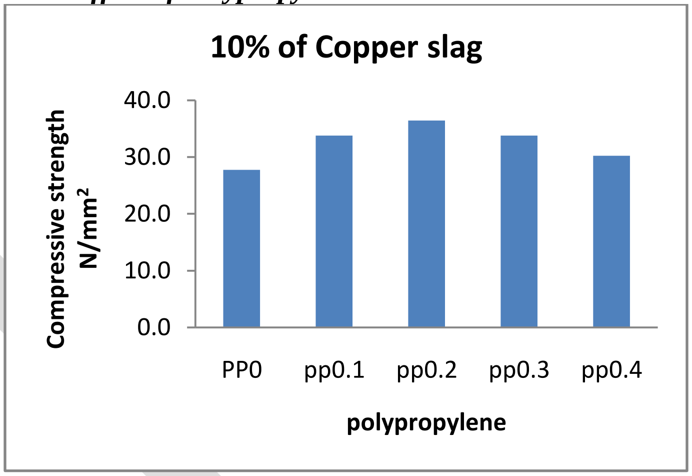


Fig 6.7 Compressive Strength for 10%Copper Slag

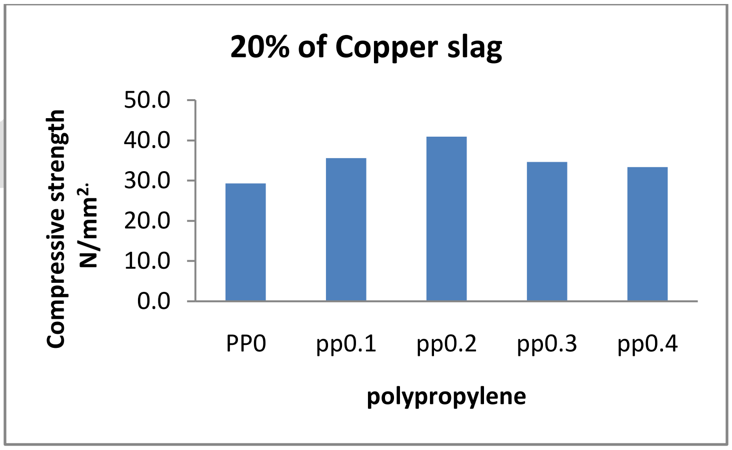


Fig 6.8 Compressive Strength for 20%Copper Slag

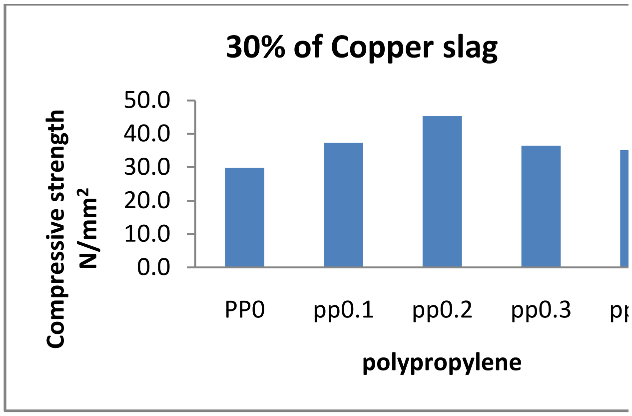


Fig 6.9 Compressive Strength for 30%Copper Slag

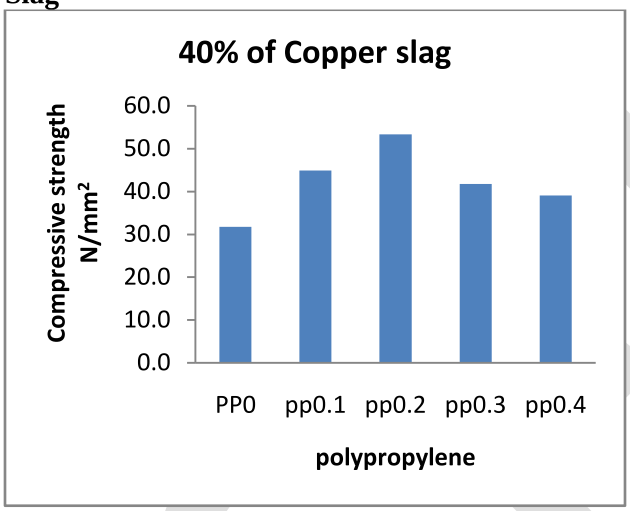


Fig 6.10 Compressive Strength for 40%Copper Slag

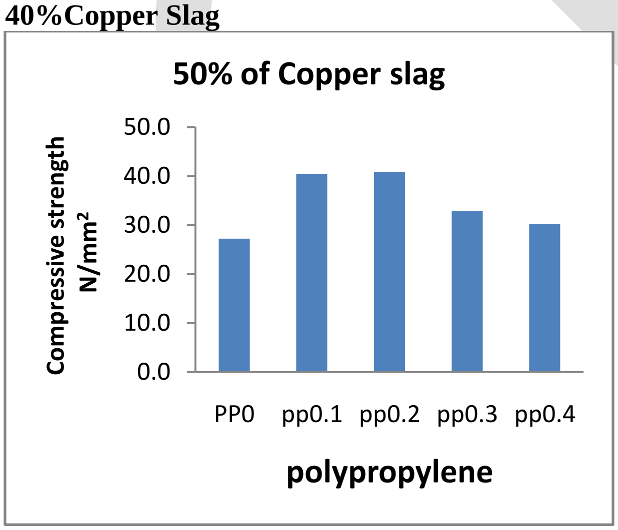


Fig 6.11 Compressive Strength for 50%Copper Slag

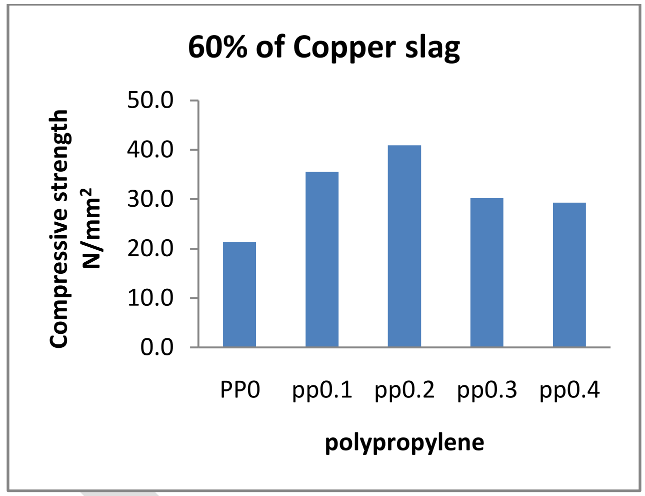


Fig 6.12 Compressive Strength for 60%Copper Slag

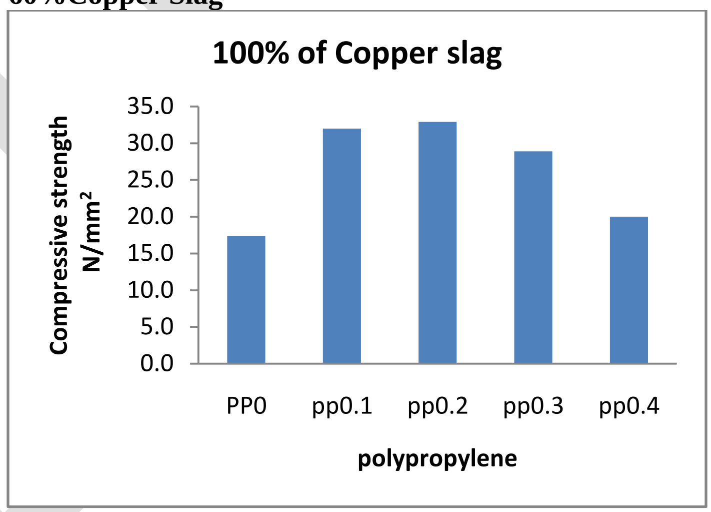


Fig 6.13 Compressive Strength for 100%Copper Slag

Percentage Increase in Compressive Strength on 7th Day

Table 6.3 7th Percentage Increase in Compressive Strength on 7th Day

	CS10	CS20	CS30	CS40	CS50	CS60	CS100
PP0	-	-	-	-	-	-	-
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	11.1	7.8	-26.5

Effect of polypropylene

i. **For 10% Copper slag**

The maximum compressive strength of 53.3N/mm^2 was obtained for 0.2%of polypropylene fibre. The compressive strength is increased by 24.2%, 34%, 24.2%, and 11.1% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

ii. **For 20% Copper slag**

The maximum compressive strength of 53.3N/mm^2 was obtained for 0.2%of polypropylene fibre. The compressive strength is increased by 30.4%, 50.3%, 27.5%, and 22.5% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

iii. **For 30% Copper slag**

The maximum compressive strength of 53.3N/mm^2 was obtained for 0.2%of polypropylene fibre. The compressive strength is increased by 37.3%, 66.7%, 34%, and 29.1% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

iv. **For 40% Copper slag**

The maximum compressive strength of 53.3N/mm^2 was obtained for 0.2%of polypropylene fibre. The compressive strength is increased by 65%, 96.1%, 53.6%, and 43.8% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

v. **For 50% Copper slag**

The maximum compressive strength of 53.3N/mm^2 was obtained for 0.2%of polypropylene fibre. The compressive strength is increased by 48.7%, 50.3%, 20.9%, and 11.1% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

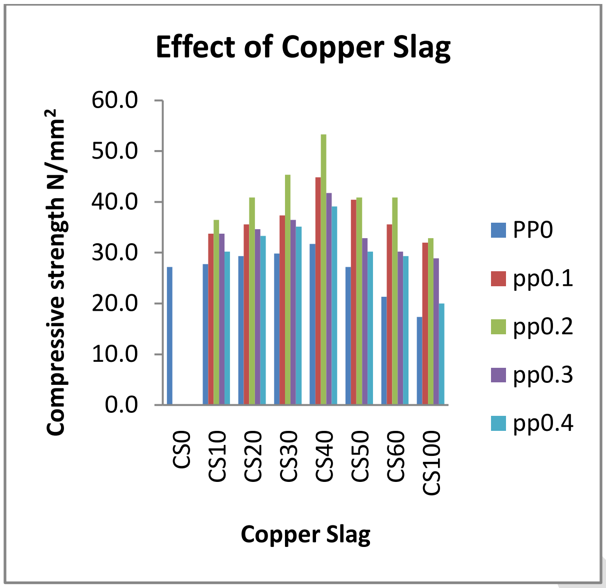
vi. **For 60% Copper slag**

The maximum compressive strength of 53.3N/mm^2 was obtained for 0.2%of polypropylene fibre. The compressive strength is increased by 30.7%, 50.3%, 11.1%, and 7.8% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

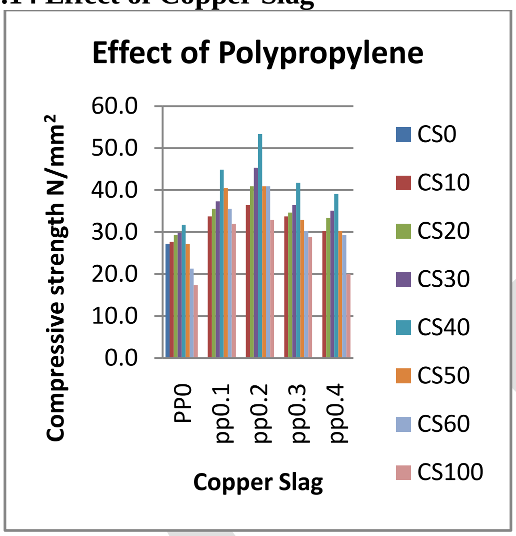
vii. **For 100% Copper slag**

The maximum compressive strength of 53.3N/mm^2 was obtained for 0.2%of polypropylene fibre. The compressive strength is increased by 17.6%, 20.9%, 6.2%, for 0.1%, 0.2%, 0.3% polypropylene fibre. The compressive strength is decreased by -26.5% for 0.4% fibre content. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

6.3.3 Comparison of compressive strength results after 7days



6.14 Effect of Copper Slag



6.15 Effect of polypropylene

6.4 Compressive Strength after 28 Days

Table 6.4 Compressive Strength -Ultimate Loads (kN) after 28 days

	CS0	CS10	CS20	CS30	CS40			
PP0	720	774	786	797	1280	1200	820	800
pp0.1	-	823	910	1270	1303	1250	835	830
pp0.2	-	890	940	1290	1360			
pp0.3	-	847	907	1030	1173			
pp0.4	-	690	760	1010	1080			

Table 6.5 Compressive Strength (N/mm^2) after 28 days

6.4.1 Effect of Copper Slag

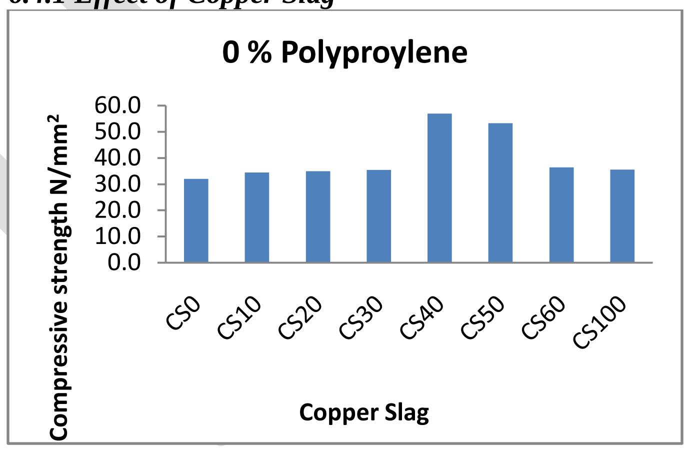


Fig 6.16 Compressive Strength for 0%Polypropylene

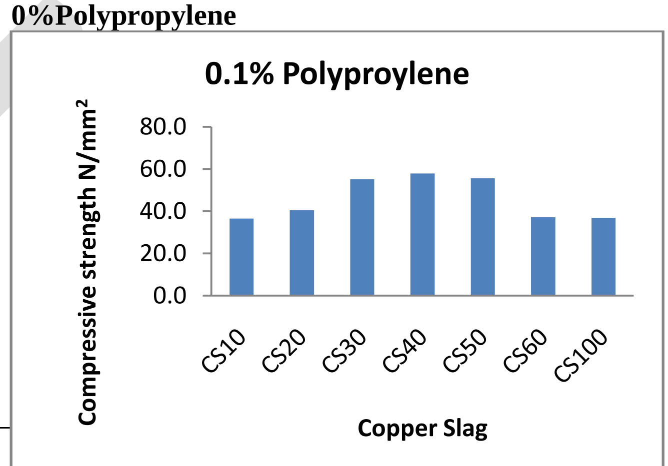


Fig 6.17 Compressive Strength for 0.1%Polypropylene

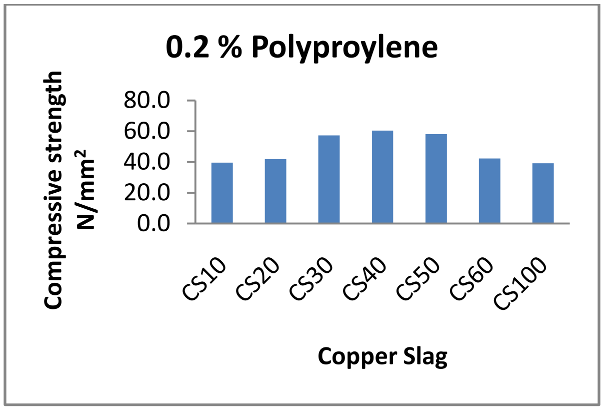


Fig 6.18 Compressive Strength for 0.2%Polypropylene

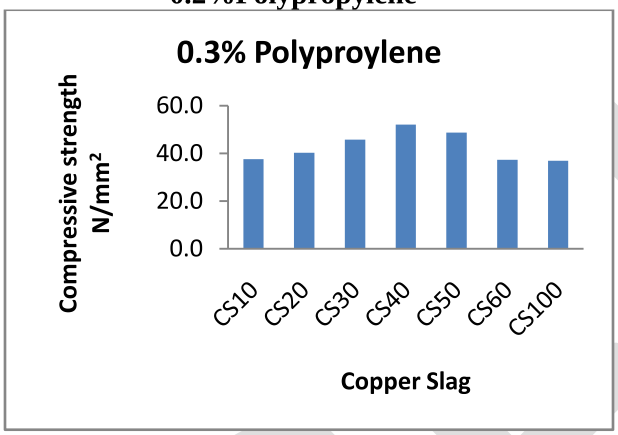


Fig 6.19 Compressive Strength for 0.3%Polypropylene

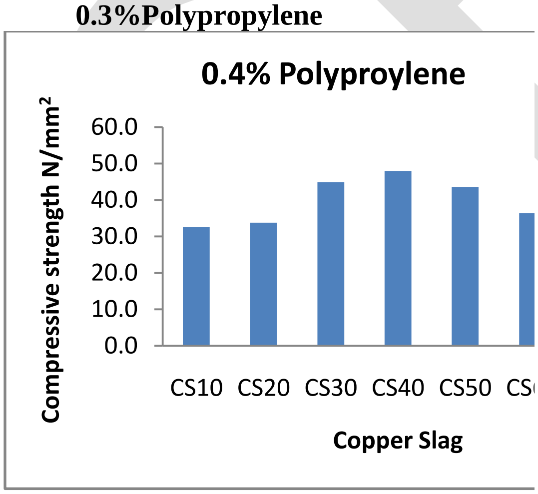


Fig 6.20 Compressive Strength for 0.4%Polypropylene

i. **For 0.1% Polypropylene**

The compressive strength increases by 88.9% for 40% replacement of copper slag. The increase in compressive strength was 14.3%, 26.4%, 72.2% and 81% for 10%, 20%, 30%, and 40% for copper slag respectively. The strength decreased beyond this. However strength increased by 15.3% when the copper slag content is increased to 100% replacement of copper slag when compared to control mix

ii. **For 0..2% Polypropylene**

The compressive strength increases by 88.9% for 40% replacement of copper slag. The increase in compressive strength was 23.6%, 30.6%, 79.2% and 88.9% for 10%, 20%, 30%, and 40% for copper slag respectively. The strength decreased beyond this. However strength increased by 22.2% when the copper slag content is increased to 100% replacement of copper slag when compared to control mix

iii. **For 0.3% Polypropylene**

The compressive strength increases by 88.9% for 40% replacement of copper slag. The increase in compressive strength was 17.6%, 26%, 43.1% and 62.9% for 10%, 20%, 30%, and 40% for copper slag respectively. The strength decreased beyond this. However strength increased by 15.3% when the copper slag content is increased to 100% replacement of copper slag when compared to control mix

iv. **For 0.4% Polypropylene**

The compressive strength increases by 88.9% for 40% replacement of copper slag. The increase in compressive strength was 2.1%, 5.6%, 40.3% and 50% for 10%, 20%, 30%, and 40% for copper slag respectively. The strength decreased beyond this. However strength increased by 12.5% when the copper slag content is increased to 100% replacement of copper slag when compared to control mix

6.4.2 Effect of Polypropylene

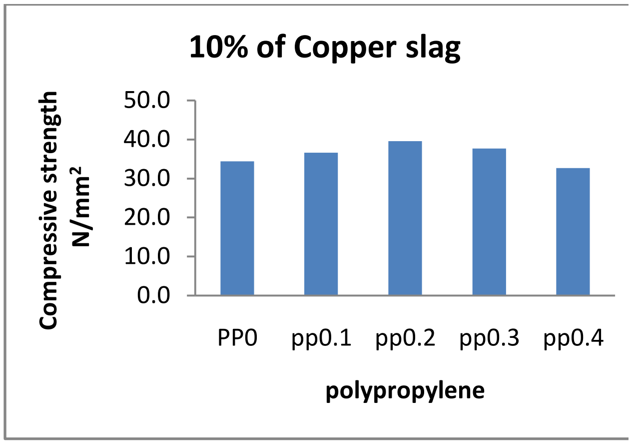


Fig 6.21 Compressive Strength for 10%Copper Slag

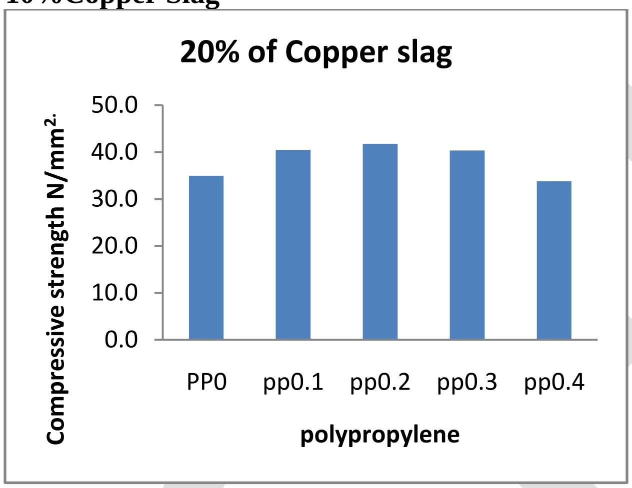


Fig 6.22 Compressive Strength for 20%Copper Slag

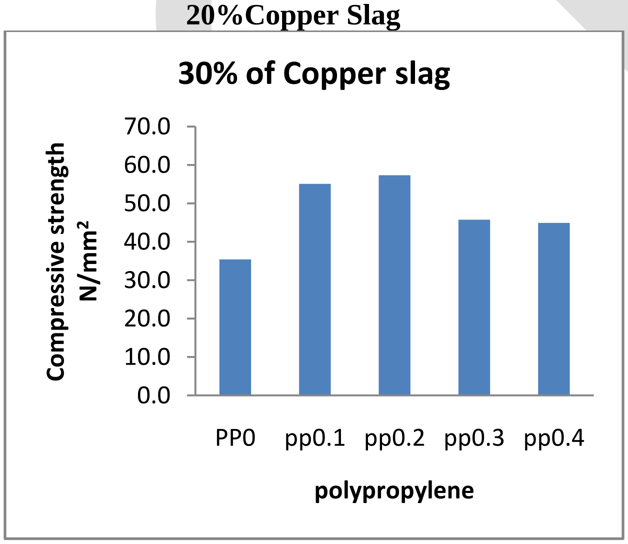


Fig 6.23 Compressive Strength for 30%Copper Slag

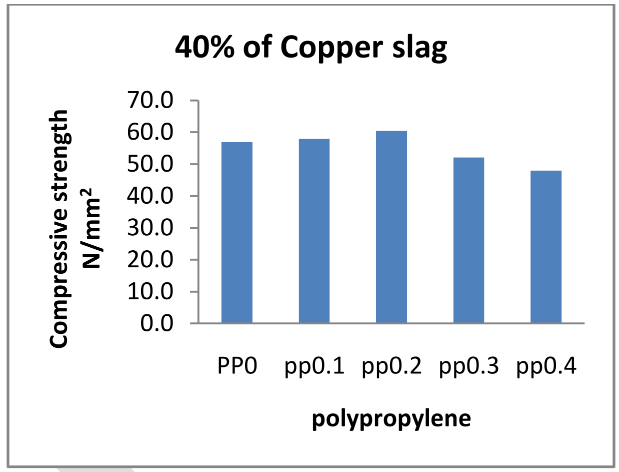


Fig 6.24 Compressive Strength for 40%Copper Slag

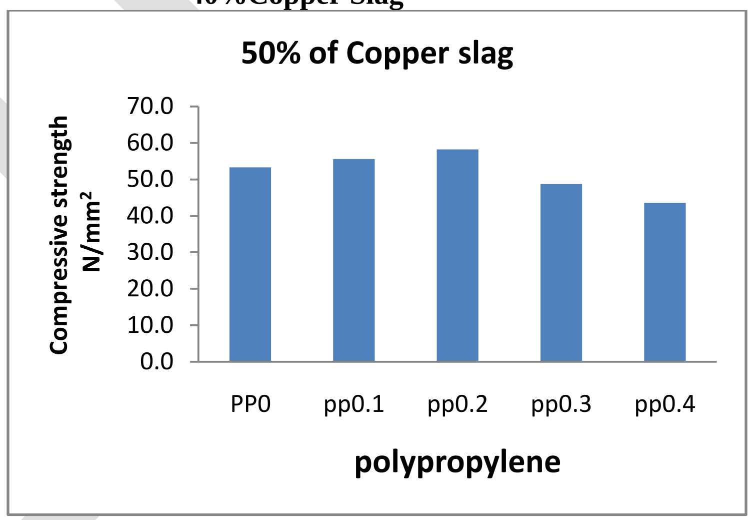


Fig 6.25 Compressive Strength for 50%Copper Slag

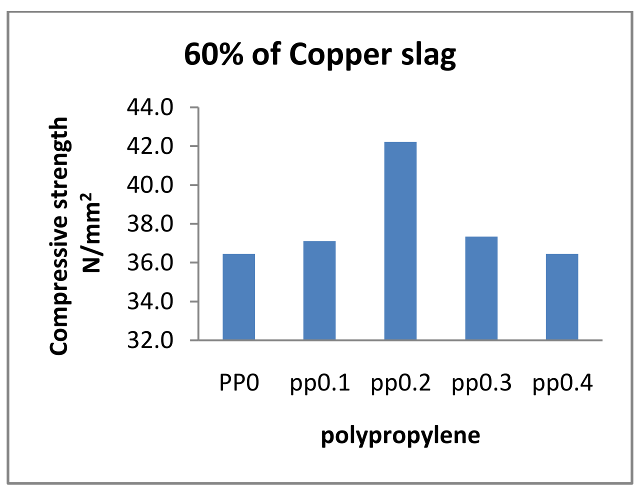


Fig 6.26 Compressive Strength for 60%Copper Slag

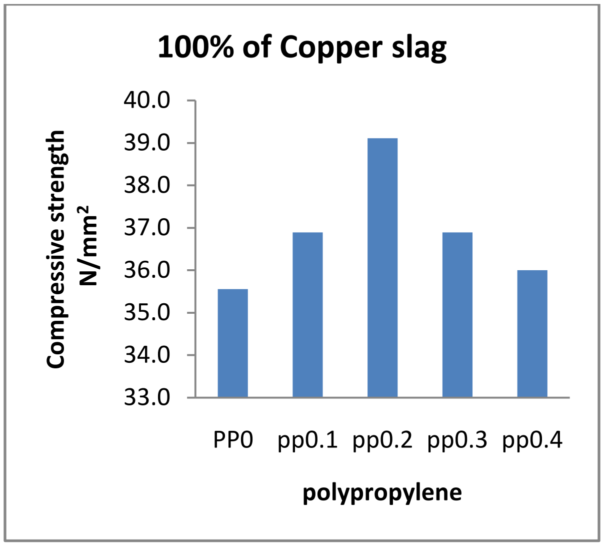


Fig 6.27 Compressive Strength for 100%Copper Slag

6.4.3Percentage Increase in Compressive Strength on 28th Day

Table 6.6 28th Day Compressive Strength

	CS10	CS20	CS30	CS40	CS50	CS60	CS100
PP0	-	-	-	-	-	-	-
PP0.1	14.3	26.4	72.2	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

Results*Effect of polypropylene*

i. **For 10% Copper slag**

The maximum compressive strength of 60.4N/mm^2 was obtained for 0.2% of polypropylene fibre. The compressive strength is increased by 14.3%, 23.6%, 17.6%, and 2.1% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

ii. **For 20% Copper slag**

The maximum compressive strength of 60.4N/mm^2 was obtained for 0.2% of polypropylene fibre. The compressive strength is increased by 26.4%, 30.6%, 26%, and 5.6% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

iii. **For 30% Copper slag**

The maximum compressive strength of 60.4N/mm^2 was obtained for 0.2% of polypropylene fibre. The compressive strength is increased by 72.2%, 79.2%, 43.1%, and 40.3% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

iv. **For 40% Copper slag**

The maximum compressive strength of 60.4N/mm^2 was obtained for 0.2% of polypropylene fibre. The compressive strength is increased by 81%, 88.9%, 62.9%, and 50% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

v. **For 50% Copper slag**

The maximum compressive strength of 60.4N/mm^2 was obtained for 0.2% of polypropylene fibre. The compressive strength is increased by 73.6%, 81.6%, 52.2%, and 36.1% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

vi. **For 60% Copper slag**

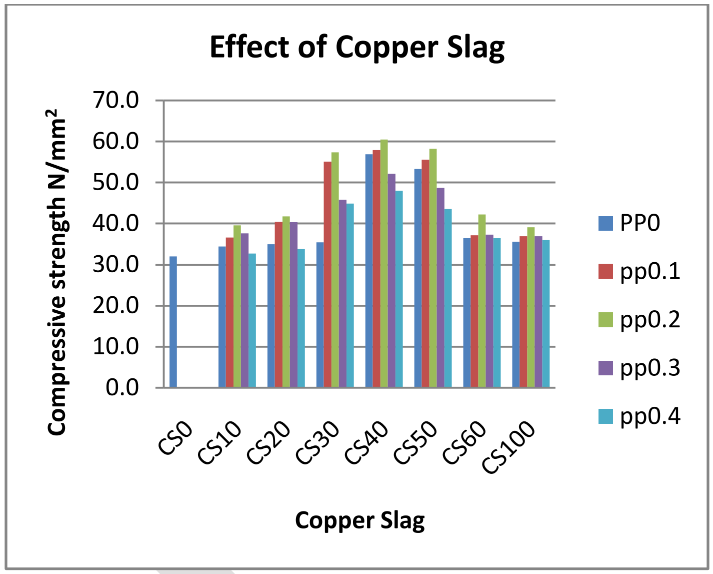
The maximum compressive strength of 60.4N/mm^2 was obtained for 0.2% of polypropylene fibre. The compressive strength is increased by 16%, 31.9%, 16.7%, and 13.9% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre.

The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

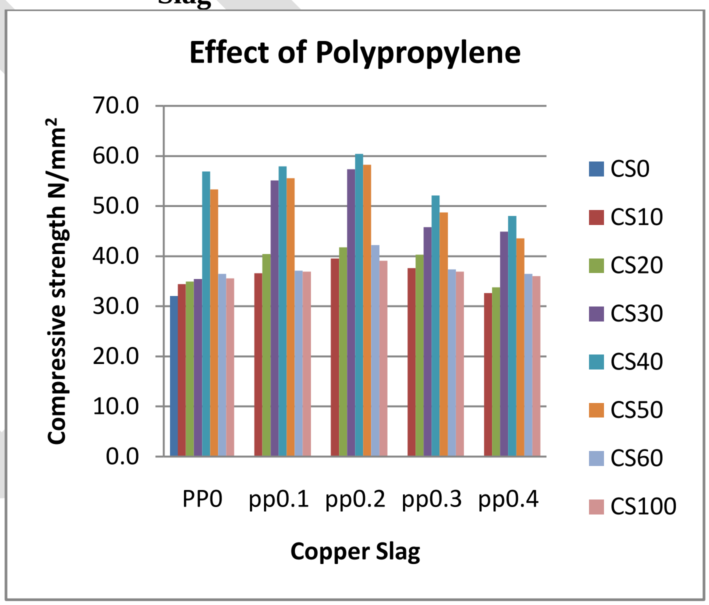
vii. **For 100% Copper slag**

The maximum compressive strength of 60.4N/mm^2 was obtained for 0.2% of polypropylene fibre. The compressive strength is increased by 15.3%, 22.2%, 15.3%, and 12.5% for 0.1%, 0.2%, 0.3% and 0.4% of polypropylene fibre. The compressive strength increased upto 0.2% and beyond 0.2% of fibre content the strength decreased. Hence it is evident that the most optimum fibre content is 0.2%

6.4.4 Comparison of compressive strength results (28days)



6.28 Effect of Copper Slag



6.29 Effect of Polypropylene

CONCLUSIONS

From the study of the effect of copper slag replacement and polypropylene fibres on the concrete properties, the following conclusions are obtained.

- The utilization of copper slag as a partial replacement for sand; imparts strength up to 40% replacement. It can be applied for all construction activities.
- A maximum Compressive strength of 60.4 was achieved when copper slag at 40% and 0.2% of polypropylene the increase in strength is compared with control mix is 89%
- Addition of slag in concrete increases the density thereby the self weight of the concrete and thus compaction.
- The recommended percentage replacement of sand by copper slag is 40%
- Copper slag is shown to significantly increase the compressive strength of concrete mixtures.

- This is an eco-friendly concrete as it subsides the stagnation of waste copper slag by consuming it.
- Shrinkage strain increases with increase in the copper slag content. The shrinkage is observed when 60% copper slag is used

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