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Effect of copper slag on mechanical properties of concrete as a partial replacement of fine aggregate

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Abstract-Conservation of natural resources and preservation of environment is necessary thing. Rapid growth of industrialization has resulted the generation of huge quantity of wastes, both in solid and liquid in industrial sectors. It's presumed that about 10-15% of wastes produced are hazardous and generation of hazardous wastes is increasing at the rate of 2- 5% per year. These generated waste were dumped on land or discharged in to water bodies and thus becomes a large source of environment pollution and health hazards. This study presents the information about utilization of industrial wastes as a suitable material for construction purposes, by which cost of construction can be reduced and also a safe disposal of waste materials can be achieved. In the present study in concrete fine aggregates will be partially replaced by copper slag from 0-100% and optimal mix for M30 grade and M40 grade concrete is found out . The strength parameters such as compressive strength, split tensile and flexural strength is confirmed for 7 and 28 days of curing period .Based on the test appropriate results is derived.

Key word- Concrete, Compressive strength, Copper slag, Split tensile, Flexural strength

I.INTRODUCTION

Concrete is the best vital material for the construction of high rise buildings and many substructures. It is the widely used man-made building materials in the world. Somewhat more than a ton of concrete is created each year for every human being on the world. Infrastructure development in such regions, mainly in evolving countries resembling India, is more. Concrete is a combination of cement, fine aggregate, coarse aggregate, water and sand is the chief raw material used as fine aggregate in the manufacture of concrete. The normal sources of river sand are getting exhausted progressively. The response for the guard of the natural environment and the ban on mining in some zones is further creating the problem of availability of river sand. At present day, the construction industry is afflicted with the insufficiency of this essential component material of concrete. Basically, concrete is inexpensive, strong, and long lasting. Although concrete technology changes its gear, the industry continue to rise to the stress of a changing market. The construction industry recognizes that substantial improvements are essential in production, product concert, energy efficiency and environmental performance. The industry wants to face and prevail over a number of institutional, competitive and technological challenges. One of the chief challenges with the environmental consciousness and shortage of space for land-filling is the waste by-products consumption as an alternative to discarding. All the way through the engineering sector, including the concrete production, the cost of environmental fulfillment is high. Use of industrial by-product such as foundry sand, fly ash, bottom ash and slag can answer in significant improvement largely in industry energy efficiency and environmental presentation. . Natural sources of aggregates are decreasing at a very high rate, specially of fine aggregates. It becomes necessary to find alternate sources of aggregates to overcome with the scarcity of resources. The production of waste products from industries becomes a bigger issue because of dumping and their hazardous effects on the environment and human health. For long time research has been carried out to check feasibility of industrial by products as supplementary material for natural materials used in concrete for a sustainable development.

II. LITERATURE REVIEW

Tamil Selvi, Ramya G, have investigated the use of copper slag as a replacement of fine aggregate in concrete. According to this study, the various strength of concrete like compressive, flexural and split tensile were studied and non-destructive test such as rebound hammer test and ultrasonic pulse velocity measurement were studied for various replacements of fine aggregate using copper slag that are 0%, 20%, 40%, 60%, 80% and 100%. The maximum compressive strength of concrete attained at 40% replacement of fine aggregate at 7 and 28 days. The split tensile strength and the flexural strength were also obtained higher strength at 40% replacement level at 28 days. The rebound hammer test showed higher compressive strength at 40% fine aggregate replacement.

R.R.Chavan, D.B.Kulkarni, have reported an experimental program to investigate the effect of using copper slag as a replacement of fine aggregate on the strength properties. For this research work, M25 grade concrete was used and tests were conducted for various proportions of copper slag replacement with sand of 0 to 100% in concrete. The results were compared with the nominal concrete tool.

J Anne Mary, investigated the use of copper slag as partial replacement of fine aggregate and reported that, the strength characteristics of copper slag incorporated concrete was found out by replacement of 20%, 40%, 60%, 80% and 100 %, out of this 40% replacement gives highest compression strength at 28 days, more than 37.55 % higher in compression strength and 5.3% higher in Split Tensile Strength and 40.72% in flexural strength compare to conventional mix.

M.V.Patil,Y.D.Patil ,have investigated technical feasibility of using copper slag as a replacement of fine aggregate in concrete. For this research work, m30 grade concrete was used and tests were conducted for various proportions of copper slag replacement with sand of 0 to 100% in concrete. As the percentage of Copper slag increases the density of concrete was increased. Density was increased by 7% due to replacement of fine aggregate at 100%.Maximum modulus of elasticity of copper slag concrete increased by 15.22% at 40% replacement of fine aggregate, and up to 60% replacement, concrete gain more modulus of elasticity than normal concrete. It was found that the permeability up to 40 % was decreased and after that the permeability was increased from 50 % to 100% replacement .Replacement of copper slag in fine aggregate reduces the cost of making concrete.

A. Objective:

In this study the properties of concrete like workability, compacting factor compressive strength, are found out for partial replacement of fine aggregate with copper slag.

III. MATERIAL AND WORK

A) Material: Preliminary testing on cement is done to check the quality of cement and these parameters are used for making the model using artificial neural network.

1) Cement: Cement is used for investigation was 53 Grade ordinary Portland cement confirming to Indian Standard (IS): 12269[5].The physical properties of cement are as given in table no 1.

Table 1: Physical properties of cement

Properties	Results
1)Specific gravity	3.1
2)Standard consistency	35%
3)Initial setting time	55min
4)Final setting time	284min
5)Fineness modulus	2.1%

2) Water: The demand of water increases with increase in fineness of source material for same degree of workability .So the minimum quantity of water is selected on the basis of workability ,fineness of copper slag and grading of fine aggregate.

3) Fine aggregate: The aggregate which passes through BIS test sieve number 4 (4.75mm) is termed as fine aggregate usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as fine aggregates. In our region fine aggregate, it conforms to IS 383 1970 [6] comes under zone II. The physical properties of fine aggregate are given in table 2

Table 2: Physical properties of fine aggregate

Properties	Results
1.Fineness modulus	3.24
2.Specific gravity	2.73
3.Water absorption	0.3

4) Coarse aggregate: The material which is retained on BIS test sieve number 4 (4.75mm) is termed as coarse aggregate. The broken stone is generally used as a stone aggregate. Coarse aggregate used is locally available crushed angular aggregate of size 20mm and 10mm are used for this experimental work. Table no 3 shows physical properties.

Table 3: Physical properties of coarse aggregate

Properties	Results
1.Fineness modulus	6.87
2.Specific gravity	2.69
3.Water absorption	0.4

5) Copper slag: Copper slag is an industrial by-product material produced from the process of manufacturing copper. Copper slag used in this work was brought from Hindalco industries pvt ltd at dahej in Bharuch district ,Gujrat state. Physical and chemical composition of copper slag is as given in table 4 and table 5 shows chemical composition.

Table 4: Physical properties of copper slag

Properties	Results
1.Appearence	Black and glassy
2.Type	Air cooled
3.Specific gravity	3.51
4.Fineness modulus	3.38

Table 5: Chemical composition of copper slag

Element	Concentration (%)
1.Silicon	34.60
2.Alluminium	3.879
3.Mangnese	60.49
4.Magnesium	1.463
5.Pottasium	1.022
6.Calcium	4.649

B) *Mix design:* It is most important part of manufacturing of concrete considering all aspects of concrete like compression strength, durability and workability is satisfied. Various trial mixes are taken and finally a formidable mix is adopted giving the desired results. The method adopted for mix design is as per IS 10262[7].And arrived mix ratio was 1:1.35:2.51:0.41, table 6 and table 7 shows the details.

Table 6: Mix proportion (kg/m^3) for M40 grade concrete and mix ratio

Cement	Fine aggregate	Coarse aggregate	w/c ratio
450	609.40	1130.09	185
1	1.35	2.51	0.41

Table 7: Mix proportion (kg/m^3) for M30 grade concrete and mix ratio

Cement	Fine aggregate	Coarse aggregate	w/c ratio
449	785	1055	193.07
1	1.74	2.34	0.45

Table 8: Various concrete mixes for M40 grade concrete

Sr no	% replacement of fine aggregate	Cement (Kg/m^3)	Fine aggregate (Kg/m^3)	Copper slag (Kg/m^3)	Coarse aggregate (Kg/m^3)	Water (Kg/m^3)
1.	0	450	609.40	0	1130.09	185
2.	10	450	548.46	60.94	1130.09	185
3.	20	450	487.52	121.88	1130.09	185
4.	30	450	426.58	182.82	1130.09	185
5.	40	450	365.64	243.76	1130.09	185
6.	50	450	304.7	304.66	1130.09	185
7.	60	450	243.76	365.04	1130.09	185
8.	75	450	152.35	457.05	1130.09	185
9.	90	450	60.94	548.46	1130.09	185
10.	100	450	0	609.40	1130.09	185

Table 9: Slump cone and compacting factor test for M40 grade concrete

Replacement of fine aggregate%	Slump (mm)	Compacting factor	Degree of workability
0	25	0.81	Low
10	25.5	0.83	Low
20	26.5	0.85	Low
30	28.4	0.87	Low
40	29.3	0.89	Low
50	30.2	0.91	Low
60	31.3	0.93	Low
75	33.5	0.94	Low
90	34	0.95	Low
100	38	0.97	Low

Table 10: Slump cone test for M30 grade concrete

Replacement of fine aggregate%	Slump (mm)	Degree of workability
0	47	Medium
10	50	Medium
20	52	Medium
30	54	Medium
40	57	Medium
50	60	Medium
60	62	Medium
75	65	Medium
90	67	Medium
100	69.5	Medium

Fig 1: Compacting factor test and slump cone test of fresh concrete

C) Preparation of samples: The cubes were prepared and cured as per IS 10086[8] and IS 516[9] of size 150×150×150mm and were water cured for 7 and 28 days and then tested for compression test under universal testing machine of capacity 1000KN.For each replacement of fine aggregate 3 specimens were casted.

D) Strength test:

1) Compression test: By definition compressive strength of concrete is defined as ration ultimate load at failure to area of concrete specimen. It was carried as per IS 516[9] and results are given in table no 9.Fig no -2 shows the compression test Compressive strength = Ultimate load at failure (N)/Area of cross section (mm^2).

2) Split tensile strength: After water curing of cylinders of size 150×150×300 for all replacements of fine aggregate it were then tested for spilt tensile test as per IS 516[9].The results of spilt tensile for 28 days curing are given in table no 12 for M40 grade table no 15 for M30 grade concrete.

3) Flexural strength test: Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The flexural strength represents the highest stress experienced within the material at its moment of rupture .The flexural strength (N/mm2) of rectangular cross-section using a three point flexural test technique is obtained by the formula: Flexural strength: PL/BD^2

Where, P=Ultimate load at failure (N), L=Length of specimen (mm), B=Breadth of specimen (mm) and D=Depth of specimen (mm).The results are given in table no 13 for the flexural strength of concrete after 28 days of curing.

Fig2: Compressive test and split tensile test on concrete

Table 11: Average compressive strength of the M40 grade concrete at 7 and 28 days

Replacement of fine aggregate (%)	7th day compression strength (N/mm^2)	28th day compression strength (N/mm2)
0	28.50	38.70
10	32	39.2
20	33.82	40.60
30	36.8	41.7
40	38.39	43.95
50	34.8	38.62
60	30.77	34.3
75	29.70	32.6
90	29.50	31.6
100	26.50	28.66

Table 12: Average compressive strength of the M30 grade concrete 28 days

Replacement of fine aggregate(%)	28th day compression strength(N/mm2)
0	34.2
10	36.31
20	37.6
30	38.3
40	39.8
50	32.3
60	31.6
75	30.6
90	29.8
100	26.8

Table 13: Average split tensile strength of the M40 grade concrete 28 days

Replacement of fine aggregate(%)	28th day split tensile strength(N/mm2)
0	3.45
10	3.68
20	3.8
30	3.93
40	4.09
50	3.64
60	3.42
75	3.22
90	3.02
100	2.85

Table 14 : Average flexural strength of the M40 grade concrete at 28 days

Replacement of fine aggregate(%)	28^{th} day flexural strength (N/mm2)
0	4.89
10	5.8
20	6.9
30	7.24
40	7.63
50	6.87
60	6.17
75	5.5
90	4.9
100	4.44

Table 15: Average compressive strength of the M30 grade concrete at 28 days

Replacement of fine aggregate(%)	28^{th} day compression strength(N/mm2)
0	34.2
10	36.31
20	37.6
30	38.3
40	39.8
50	32.3
60	31.6
75	30.6
90	29.8
100	26.8

Table 16: Average split tensile strength of the M30 grade concrete at 28 days

Replacement of fine aggregate(%)	28^{th} day split tensile strength(N/mm2)
0	3.2
10	5.2
20	6.34
30	5.8
40	5.75
50	4.5
60	4.2
75	3.1
90	2.97
100	2.8

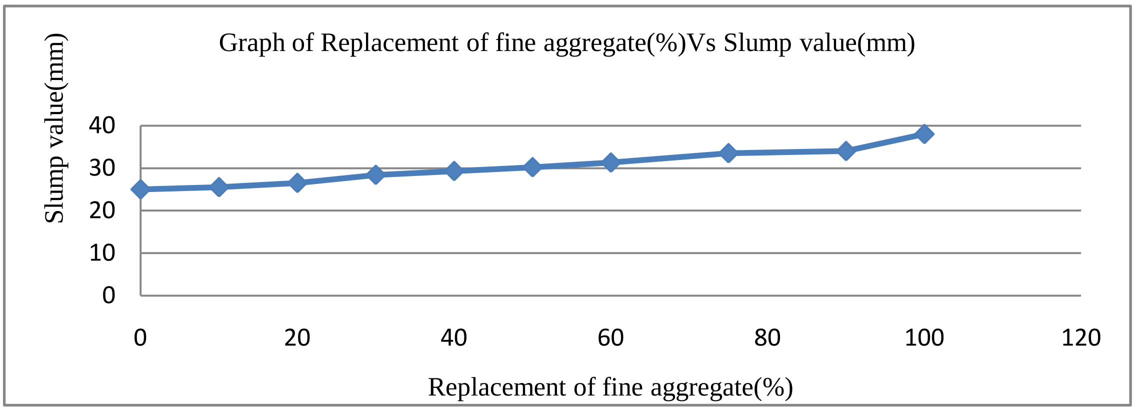

Fig 3: Relationship between fine aggregate replacement (%) and slump value (mm) for M40 grade concrete

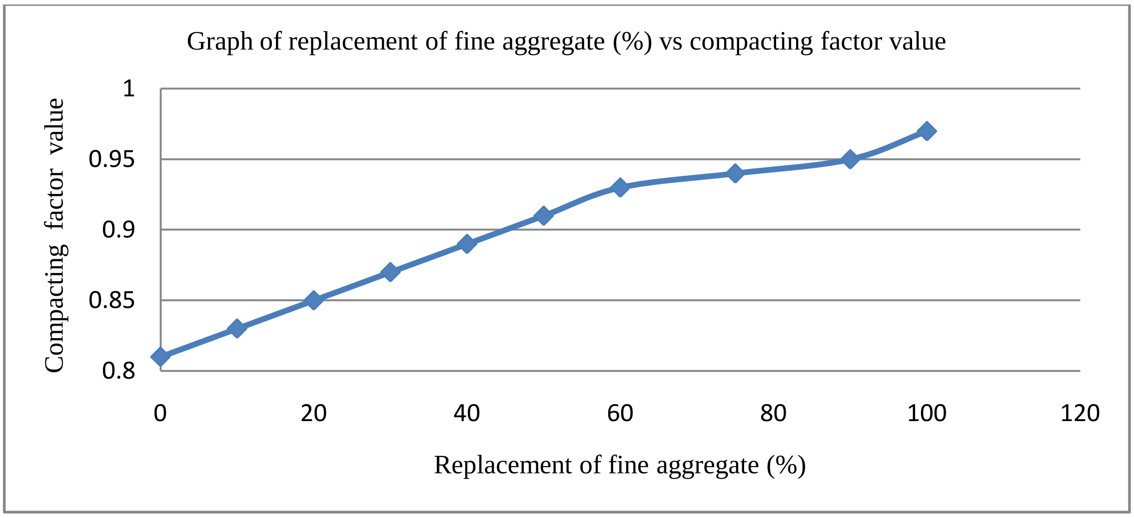

Fig 4: Relationship of replacement of fine aggregate and compacting factor for M40 grade concrete

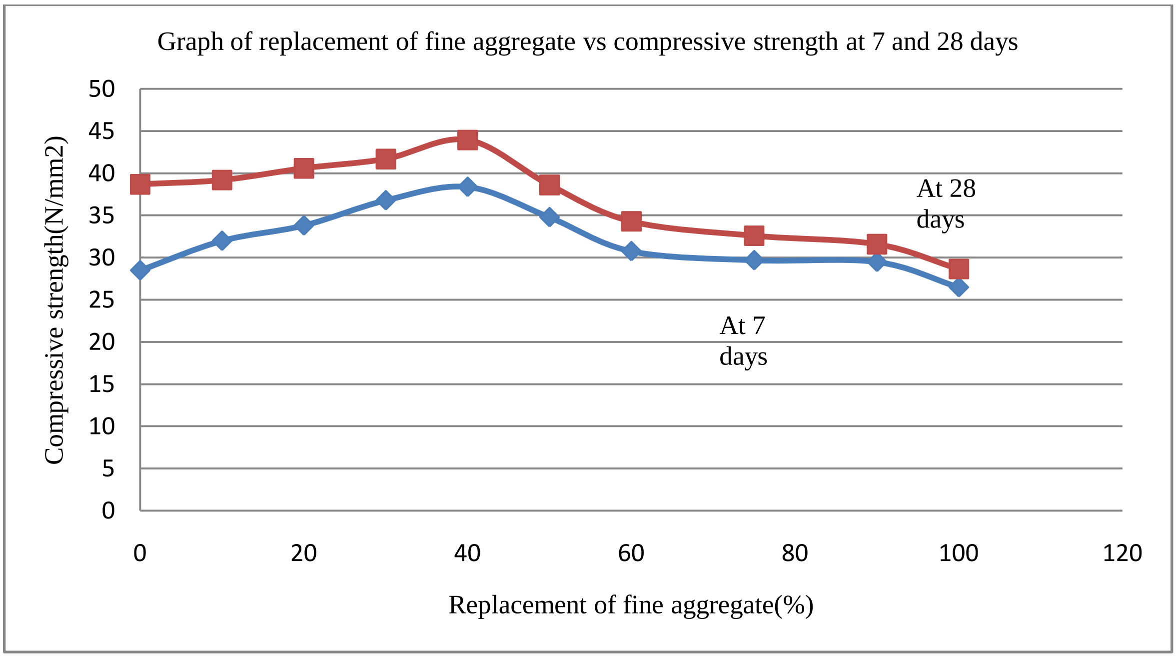

Fig 5: Relationship of replacement of fine aggregate and compressive strength at 7 and 28 days for M40 grade concrete

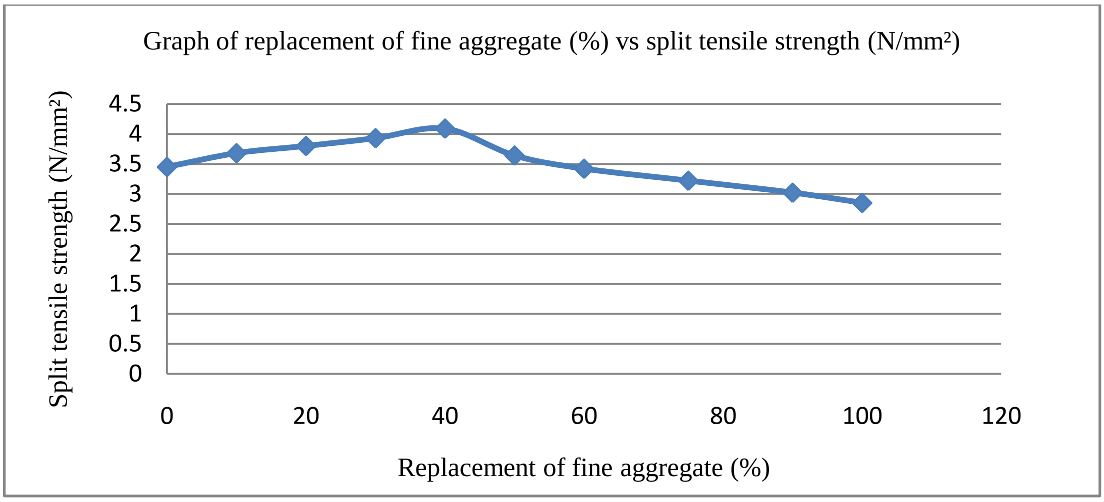

Fig 6: Relationship of replacement of fine aggregate and split tensile strength at 28 days for M40 grade concrete

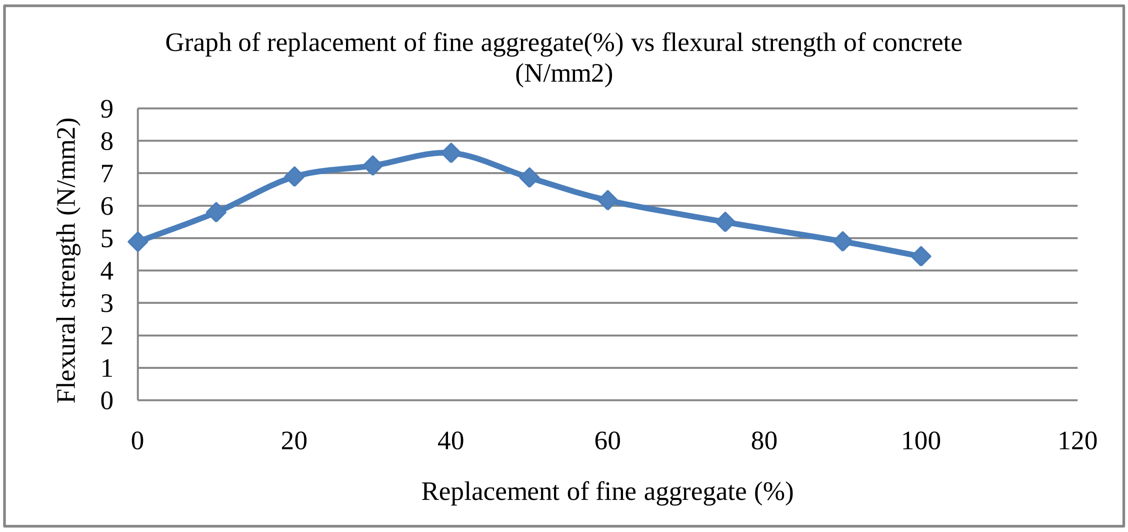

Fig 7: Relationship of replacement of fine aggregate and flexural strength at 28 days for M40 grade concrete

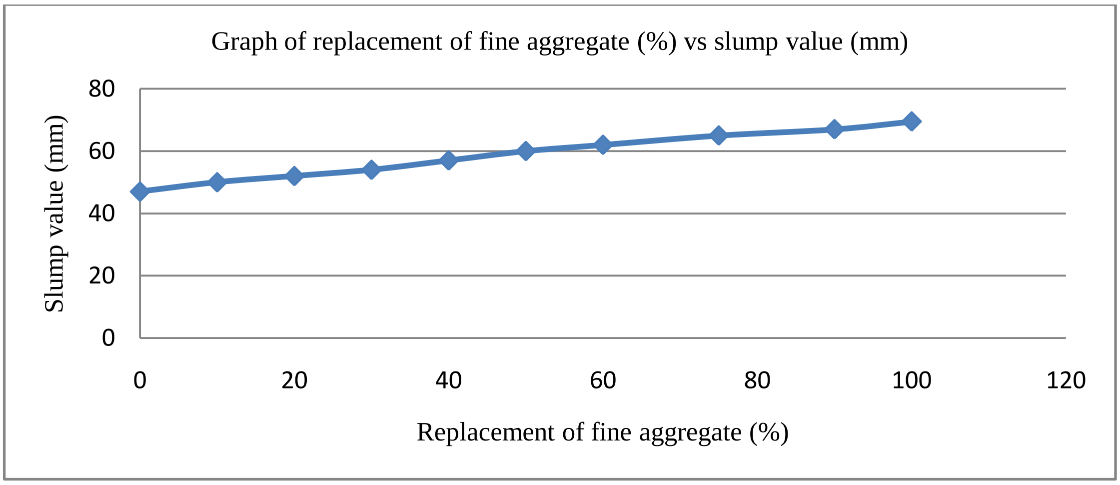

Fig 8: Relationship between fine aggregate replacement (%) and slump value (mm) for M30 grade concrete

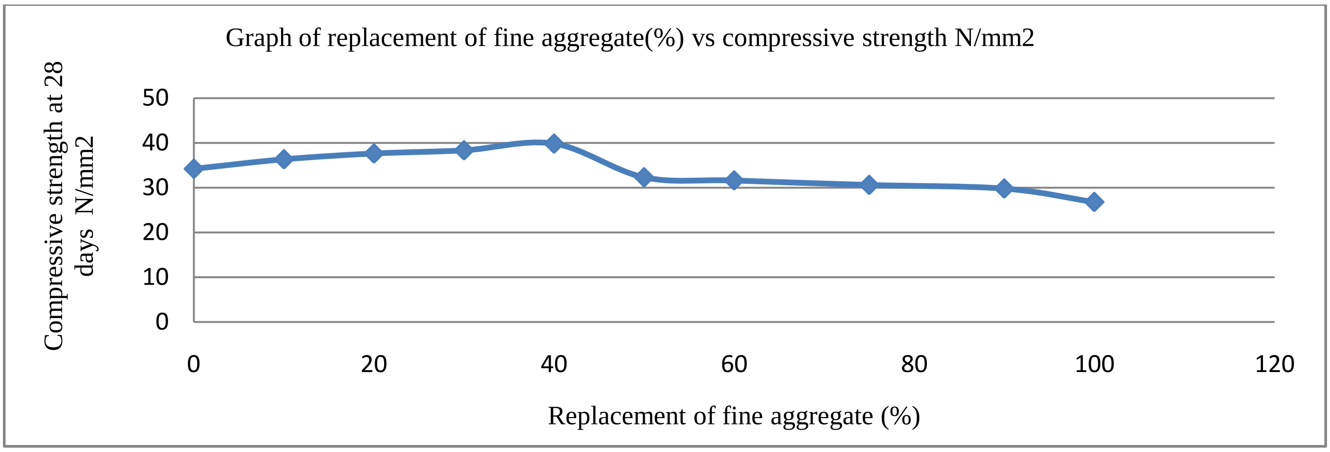

Fig 9: Relationship of replacement of fine aggregate and compressive strength at 28 days for M30 grade concrete

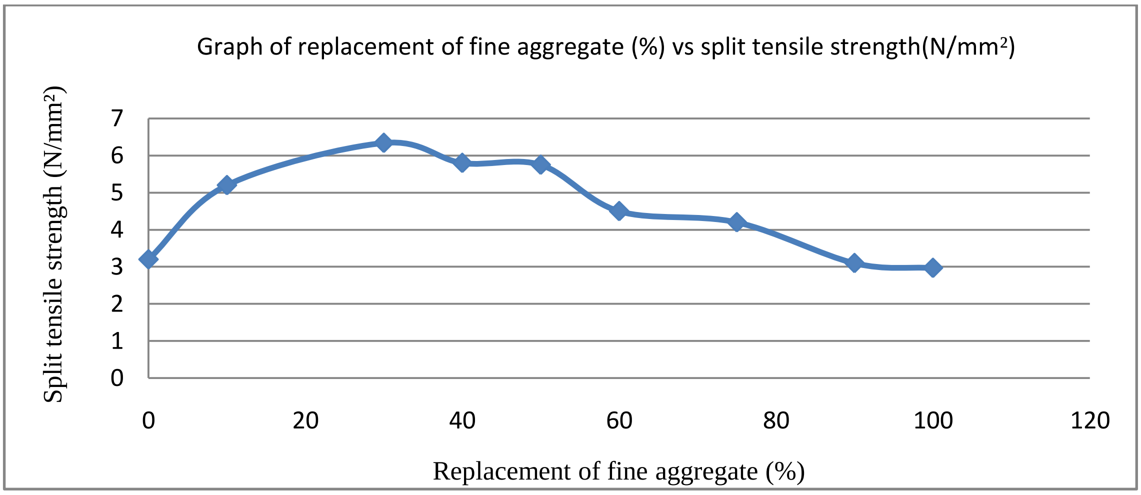

Fig 10: Relationship of replacement of fine aggregate and split tensile strength at 28 days for M30 grade concrete

IV. RESULTS AND DISCUSSION

Based on the observation and calculations that were seen during performing the experimental work , following results and discussion are given in the chapter. For the purpose of workability, slump cone test and compacting factor test was carried out and results are calculated as given in previous tables.

A) Slump value: From the fig no 3 and fig no 8 it is clear that slump value increases with increase in replacement percentage of fine aggregate. The slump measure for normal concrete for M40 grade concrete was 25mm and 38mm for 100% replacement. This notable increase in slump value is due to low water absorption and glassy surface characteristics of copper slag in concrete.

B) Compacting factor value: From the fig no 4 it was clear that increase in copper slag percent increases the compacting factor value which in turns gives highest value of 0.97 for 100% and 0.81 for 0% replacement. This was mainly due the copper slag specific gravity which was 3.51 as compare to fine aggregate used for the experimental work which was 2.73.

C) Compressive strength: From fig no 5 it was pretty clear that compressive strength of 0% was 28.5N/mm^2 and for 100 % it was 26.50N/mm^2 for 7 days and for 28 days curing it was 38.7N/mm^2 and 28.66N/mm^2 respectively. The highest value was acquired was for 40% replacement was 38.39N/mm^2 and 43.95N/mm^2 for 7 and 28 days respectively. Similar behaviour was seen for M30 grade concrete results from fig no 9.

D) Split tensile strength: From fig no 6 it is clear that split tensile strength increases as upto 40 % replacement for M40 grade concrete and upto 20 % but still greater than normal concrete of M30 grade concrete.

E) Flexural strength : From fig no 7 it can be seen that flexural strength of M40 grade concrete gradually increased upto 40 % and further decreased gradually till 100 % replacement of fine aggregate by copper slag.

V. CONCLUSION

*1)*The replacement of fine aggregate by copper slag increases the dead weight of concrete and thus increasing the density of concrete.

*2)*The workability increases for higher replacements of copper slag for fine aggregate and 100% giving the maximum value.

*3)*The concrete at higher replacements of copper slag gives the sign of segregating and bleeding which can deterioting effects on concrete performance in future.

*4)*Till 40% the fine aggregates can be successfully replaced by copper slag and thus allows the safe and easy disposal of this waste industrial material and in turn reduces demand of infill land and thus maintains the required environmental balance of society. This copper slag is also very economical as compare to fine aggregate cost and thus making concrete economical.

*5)*Considering the impact of copper slag had on the mechanical properties of concrete by replacement to fine aggregate showed satisfactory results it can be said that construction industry is safe are of disposal of this industrial waste material.

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