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Effect of copper slag and fly ash and Nano Material to strengthen the properties of concrete

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Abstract : Utilization of industrial wastes or secondary materials has encouraged the cement and concrete industries for more beneficial product generation. Re-cycling of waste materials has great potential in the concrete industry. Over the recent decades, intensive research studies have been carried out to explore all possible re-use methods. Construction waste, blast furnace slag, steel slag, coal fly ash, bottom ash etc have been accepted as alternative methods of replacement of cement and aggregates. Here in this work the materials used are copper slag and fly ash as the replacement materials. Copper slag (CS) is an industrial by-product produced from the manufacturing of copper. It possesses mechanical and chemical characteristics that qualify it to be a partial replacement material of Portland cement as well as fine aggregates. Fly ash (FA) is finely divided residue, resulting from the combustion of ground or powdered coal. It's available in large quantities as a waste product from thermal power plants and industrial plants. The properties of fly-ash contribute to strength gain and improved durability when used with Portland cement. In this work it was experimented that, what performance these two can provide when used collectively in concrete as a replacement material. Fly-ash is used as a cement replacement material whereas copper slag is used as a sand replacement material. The specimens were casted and tested for compressive test, split tensile test and durability by acid resistance. Replacement was made for 5%,10%,15%,20% for both FA and CS. And tests were conducted at 28 days. Tests show that best combination is achieved at 5%FA+20%CS. By the application of 5 % nano silica and 5 % micro silica material in the preparation concrete enhance the flexural strength.

Index Terms - Copper Slag, Compressive strength, Fly ash, Flexural strength, Nano material, Pozzolana Portland Cement.

I. INTRODUCTION

Copper slag is a modern side-effect material delivered from the method involved with assembling copper. For each huge load of copper creation, around 2.2 huge loads of copper slag are produced. It has been assessed that around 24.6 million tons of slag are produced from the world copper industry (Gorai et al 2003). Despite the fact that copper slag is generally utilized in the sand impacting industry and in the assembling of grating apparatuses, the rest of discarded with no further reuse or recovery. Copper slag has mechanical and synthetic qualities that qualify the material to be utilized in concrete as a fractional swap for Portland concrete or as a substitute for totals. For instance, copper slag has various great mechanical properties for total utilize, for example, brilliant sufficiency attributes, great scraped spot opposition and great dependability revealed by (Gorai et al 2003). Copper slag likewise displays pozzolanic properties since it contains low CaO Under actuation with NaOH, it can show cementitious property and can be utilized as incomplete or full substitution for Portland concrete. The use of copper slag for applications, for example, Portland concrete substitution in concrete, or as unrefined substance has the double advantage of dispensing with the expense of removal and bringing down the expense of the substantial. The utilization of copper slag in the substantial business as a swap for concrete can have the advantage of decreasing the expenses of removal and help in safeguarding the climate. In spite of the way that few examinations have been accounted for on the impact of copper slag substitution on the properties of Concrete, further examinations are important to get a far-reaching understanding that would give a designing base to permit the utilization of copper slag in concrete. Fly ash is the finely divided residue, resulting from the combustion of ground or powdered coal and transported by the flue gases of boilers fired by the pulverized coal. It's available in large quantities as a waste product from a thermal power and industrial plants. The amount of ash contained in coal or lignite burned in power plant can vary greatly depending on the source of coal. The fine particles of fly ash by virtue of their lightness become air borne and create health problems to all living being. Its indiscriminate disposal requires a large volume of land, water and energy. Fly ash as a siliceous or aluminous, it poses pozzolanic properties when used in concrete as a partial replacement of cement. Use of such an industrial waste has many advantages such as it improves the performance of concrete exposed to sulphate environment, deterioration caused by alkali-aggregate interaction etc. In recent times, used of fly ash in concrete has grown so much that it has become a common ingredient in concrete. the characteristics of copper slag. Copper slag, which is produced during pyro metallurgical production of copper from copper ores, contains materials like iron, alumina, calcium oxide, silica etc. This paper discusses the favorable physico-mechanical characteristics of copper slag that can be utilized to make the products like cement, fill, ballast, abrasive, aggregate, roofing granules, glass, tiles etc. Apart from recovering the valuable metals by various extractive metallurgical routes. The favorable physico-mechanical and chemical characteristics of copper slag led to its utilization to prepare various value-added products such as cement, fill, ballast, abrasive, cutting tools, aggregate, roofing granules, glass, tiles etc. The utilization of copper slag in such manners may reduce the cost of disposal. This may also lead to less environmental problems. fly ashes reduced the water requirement for test mortars. There is increase in the water requirement of concrete, when Indian fly ashes were used to replace part of cement in cement concrete. It is clasped that the exhibition, strength, and solidness of cement could be improved with the expansion of nano-silica.

Material and Methodology

Fly-ash, Copper-slag, nano silica material was used for the experimentation purpose were purchased from local vendor, Baramati MIDC, Pune, Maharashtra, India. The cement substitution materials like fly-ash are used in cement up to certain amount by weight in percentages. These materials are then tested for understanding the behaviour of and evaluating the mechanical properties of substituting materials which enhances the qualities of concrete. Even fine aggregates can be replaced by its substitutive materials like copper slag and its performance is checked. These new materials are used to checked the durability concepts to make it sustainable under environmental conditions. Fly ash is produced from the combustion of pulverized coal in industrial boilers or electric utility boilers. The nano-Fe2O3 and nano-Al_2O_3 provided by Nano Wings Private Limited, India was utilized in this research work and the expense of the nano-Fe_2O_3 and nano-Al_2O_3 were Rs.41/Kg and Rs.3010/Kg, individually. The nano-Fe_2O_3 and nano-$A_{l2}O_3$ particles with a typical molecule size of 16 and 15 nm, individually, got from a nearby market were utilized in this research work.

The blending strategies were separated into three phases. In the main stage, every one of the fasteners (concrete, fly debris, copper slag) were weighted as needs be and blended by hand until every one of the constituents blended consistently. This was to ensure every one of the fasteners were blended completely to deliver a homogenous blend. The subsequent stage includes blending the folios in with the totals for around 5 minutes. At the last stage, estimated water was added into the substantial blend. This progression was significantly critical to ensure that the water was dispersed uniformly so the substantial will have comparative water-cover proportions for each 3D shape. From that point forward, the substantial was then filled the shape.

Compressive strength test

Substantial 3D shapes of size 150mm×150mm×150mm were projected with and without copper slag. During projecting, the shapes were precisely vibrated utilizing a table vibrator. Following 24 hours, the examples were demoulded and exposed to relieving for 28 days in versatile water. Subsequent to restoring, the examples were tried for compressive strength utilizing pressure testing machine of 2000KN limit. The most extreme burden at disappointment was taken. The typical compressive strength of cement and mortar examples was determined by utilizing the accompanying condition.

$$\text{Compressive Strength (N/mm}^2) = \frac{\text{Ultimate Compressive Load (KN)}}{\text{Cross Section Area of the Specimen (mm}^2)}$$

The tests were completed on a bunch of three-fold examples and the typical compressive strength values were taken.

Split tensile strength test

Substantial cylinder of size 150 mm breadth and 300mm length were projected with consolidating copper slag as halfway substitution of sand and concrete. During projecting, the chambers were precisely vibrated utilizing a table vibrator. Following 24 hours, the examples were demolded and exposed to restoring for 28 days in compact water. In the wake of restoring, the tube-shaped examples were tried for split elasticity utilizing pressure testing machine of 2000kN limit. A definitive burden was taken and the normal split rigidity was determined utilizing the condition. $\text{Split Tensile Strength} \left(\frac{N}{mm^2}\right) = \frac{2P}{\pi LD}$

were,

P=Ultimate load at failure (N),
L=Length of cylindrical specimen (mm),
D=Diameter of cylindrical specimen (mm).

The tests were done on a bunch of three-fold examples and the typical elasticity values were taken.

Mix design for grade M-40

Initial Parameters:

1) Cement Grade- O.P.C. 53, Chettinad Cement, Concrete Grade-M_{40}.
2) Specific Gravity of Cement- 2.94
3) Fine Aggregates- Sand-Zone-II
4) Specific Gravity of F.A- 2.63
5) Coarse Aggregates- 20 mm (60%)
   10 mm (40%)
6) Specific Gravity of C.A- 2.87

Mix Design calculations:

1.Target Mean strength – (F_{ck}). Fck=f_{ck}+KS

Where, f_{ck} = Characteristics Compressive Strength at 28 K = Statistical value for risk factor

S = Standard Deviation

$F_{ck} = 40 + (1.65 \times 5) = 48.25$ N/mm^2

2. Selection of Water-Cement ratio:

From Table no. 5 of IS 456-2000, Max W/C = 0.45

Adopt W/C = 0.4

3. Selection of Sand and Water Content:

W/C = 0.4

Taking Cement upto 400 kg/m^3

As per IS 456 for M_{40} grade minimum cement content is 360 kg/m^3

Therefore, as Weight of Cement taken is 400 kg/m^3
Weight of water = 0.4 × 400
= 160 kg water
Assumed 1kg = 1 liter, Hence Water requirement is 160 liters.
Now for M_{40} as per IS Maximum cement content is 180 kg which is greater than calculated hence ok.
4. Calculation of C.A & F.A
$V = \{(W + C/S_C) + [1/(1-P) \times F.A/S_{F.A}]\} \times 1/1000$
$V = \{(W + C/S_C) + [1/(1-P) \times C.A/S_{C.A}]\} \times 1/1000$
Now as per IS – 20262, 2% is considered as air entrapment
V= 1- 0.2
= 0.98
Therefore, Weight of F.A = 606.12 kg
Weight of C.A = 1282.47 kg
Hence, Cement: F.A: C.A = 1: 1.52: 3.2
And W/C = 0.4

Experimental Investigation for Durability concepts regarding Acid Attack on Concrete:

The materials used for this purpose is as listed above in and tested as per the code provisions made in the above clauses. Even the mixes and mix proportion made according to the requirement is also mentioned in the above clause. BIS code procedure as per IS: 10262-1982 was followed for finding the mix proportions of all the concrete specimens.

Testing methods for durability assessment:

The assessment of blended concrete in acidic environment was made based on the performance from visual assessment, mass loss and strength deterioration factor.

- **Visual assessment:**

Cubical specimens of 150x150 mm were casted for visual assessment and the prepared specimens were cured in water for 28 days and were immersed in 5% HCl solutions for next 30 days. The specimens were positioned so that all sides were in contact with the solutions. The pH of the solution was regularly monitored and adjusted to keep constant by replacing the consumed solutions by fresh solutions. The visual observation of acid attack was made as per the performance scale mentioned in Table 1.

Table. 1. Scale of visual deterioration level of concrete specimens immersed in acidic solution

Scale	Deterioration level
0	No Attack
1	Very slight attack
2	Slight attack
3	Moderate attack
4	Severe attack
5	Very severe attack
6	Partial disintegration

- **Mass loss**

The concrete cubes of 150 mm size were cast for finding the mass loss due to the acid attack. The prepared cubes were cured in water for 28 days and were immersed in 5%HCl solutions for next 30 days. The initial mass and the mass of concrete specimens after the immersion period of 2, 4 weeks were measured for finding the mass loss due to the deterioration of concrete specimens. The average value of three specimens was considered for assessment.

- **Strength deterioration factor (SDF)**

The strength deterioration of the concrete specimen was examined by the measurement of the strength of specimen concrete cube. deterioration factor expressed in (%) percentage and it was designed by using the following equation -

$$SDF = \left[\frac{(f_{cw} - f_{ca})}{f_{cw}}\right] x\ 100$$

(fcw) is the specific compressive strength of substantial solid shapes restored in water and (fca) is the typical compressive strength of 3D squares inundated in corrosive arrangements. The compressive strength test was done for every example in both the arrangements following a month of submersion period. In each trial, the typical worth of three examples was tried and announced

Results and Discussion

Results of fresh and hardened concrete with partial replacement of Fly ash and copper slag in combination are discussed in comparison with those of normal concrete.

For the combinations of concrete mixes three cubes were being casted each for varying curing days 3,7, 28 days & three cylinders were being casted for curing period of 28 days. Test for the same being conducted under compressive testing machine of capacity 2000KN.The strength of plain concrete achieved in 3 days, 7^{th} days and 28^{th} days were mentioned in table 2-4 respectively.

Table 2 Strength of plain Concrete

(3 days)				
Sr. No.	Area	3 days strength		Avg. Strength
		Load (KN)	Strength (N/mm^2)	
1	22500	502.20	22.32	21.33
2		485.10	21.56	
3		452.50	20.11	
(7 days)				
4	22500	679.70	30.21	29.23
5		662.60	29.45	
6		630.70	28.03	
(28 days)				
7	22500	952.20	32.44	41.67
8		944.55	32.67	
9		915.95	32.89	

Table 3 illustrated that the by the replacement of fly ash 5 %, 10 %, 15 %, and 20 % the strength of concrete is deceased.

Table 3. Strength of the concrete by replacement of Fly Ash Replacement (28 days)

5% Fly Ash Replacement (28 days)			
Area	Strength		Avg. Strength
	Load (KN)	Strength (N/mm^2)	
22500	924.50	41.09	40.32
	914.20	40.63	
	882.90	39.24	
10% Fly Ash Replacement (28 days)			
22500	899.55	39.98	39.53
	872.10	38.76	
	896.65	39.85	
15% Fly Ash Replacement (28 days)			
22500	860.40	38.24	38.02
	852.10	37.87	
	853.85	37.95	
20% Fly Ash Replacement (28 days)			
22500	827.10	36.76	36.94
	854.10	37.56	
	821.25	36.50	

Strength behavior of PCC against other replacement materials for various durations.

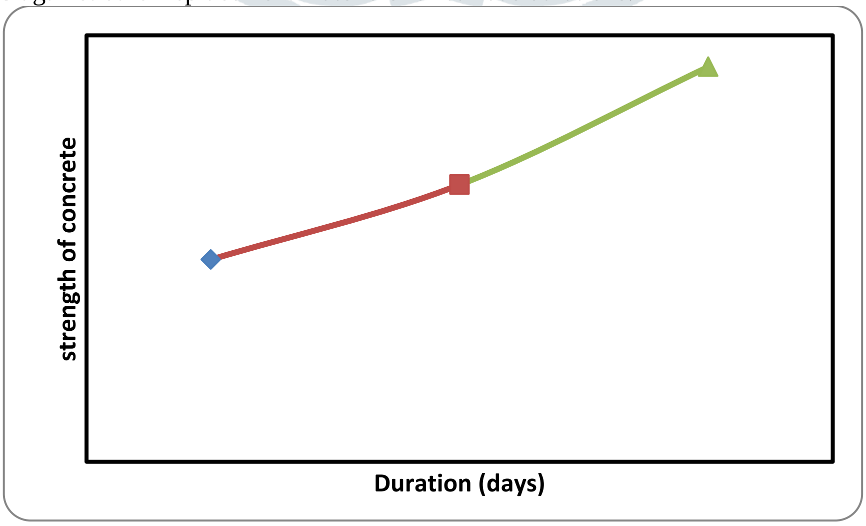

Figure 1 Compressive Strength of PCC

Within 3 days concrete achieves more than half strength of designed strength. After 7 days it achieves nearly about 70% strength of designed strength. After 28 days it achieves full strength of designed strength.

5 % Replacement by Fly Ash for Various Durations

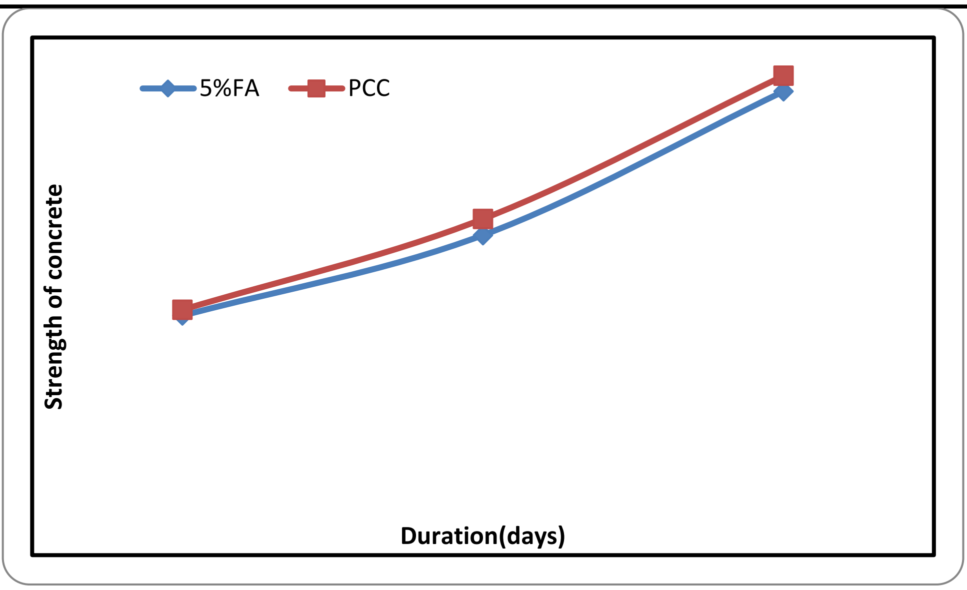

Figure 2. Strength result of 5% replacement by Fly Ash for Cement in Concrete.

Within 3 days concrete strength is almost equal to P.C.C. After 7 days strength of P.C.C is greater than concrete replacement by 5% Fly Ash which is the turning point of increase in strength. After 28 days it achieves nearly 101% strength of design strength.

10 % Replacement by Fly Ash for Various Durations

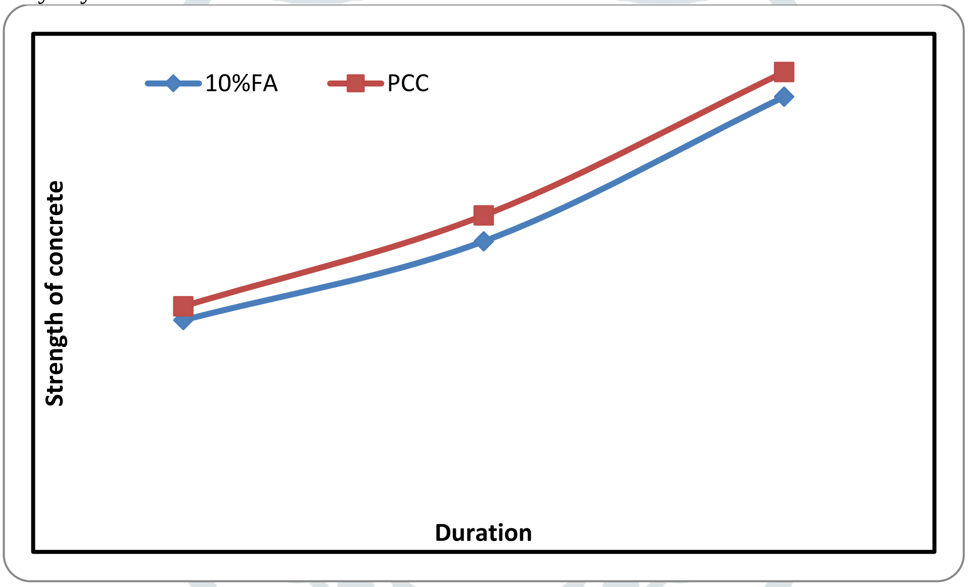

Figure 3. Strength result of 10% replacement by Fly Ash for Cement in Concrete

Within 3 days concrete strength is almost equal to P.C.C. After 7 days strength of P.C.C is greater than concrete replacement by 10% Fly Ash. After 28 days strength of P.C.C is greater than concrete replacement by 10% Fly Ash.

20 % Replacement by Fly Ash for Various Durations

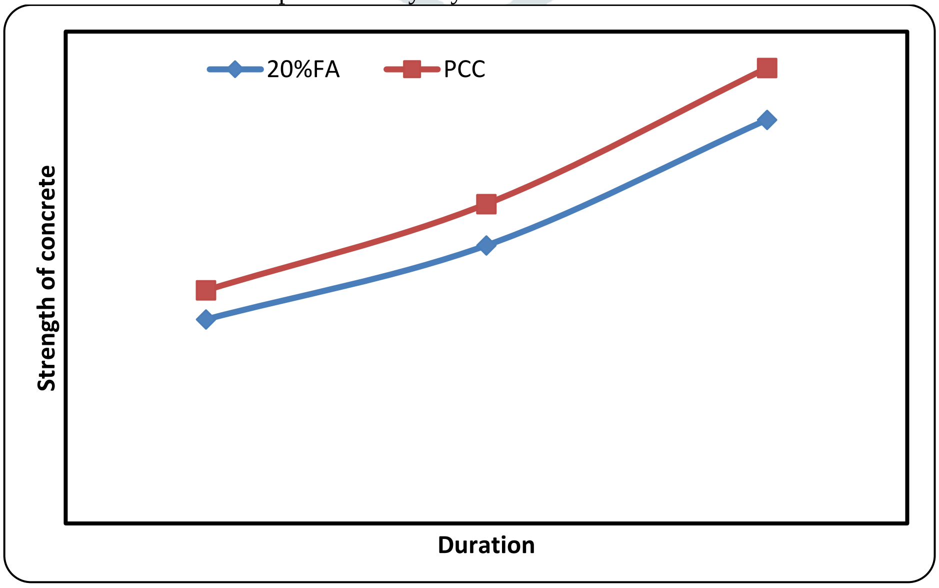

Figure 4. Strength result of 20% replacement by Fly Ash for Cement in Concrete

- After 3 days strength of P.C.C is greater than concrete replacement by 20% Fly Ash
- After 7 days strength of P.C.C is greater than concrete replacement by 20% Fly Ash

- After 28 days strength of P.C.C is greater than concrete replacement by 20% Fly Ash.

Results of 5 % Replacement by Copper Slag for Various Durations

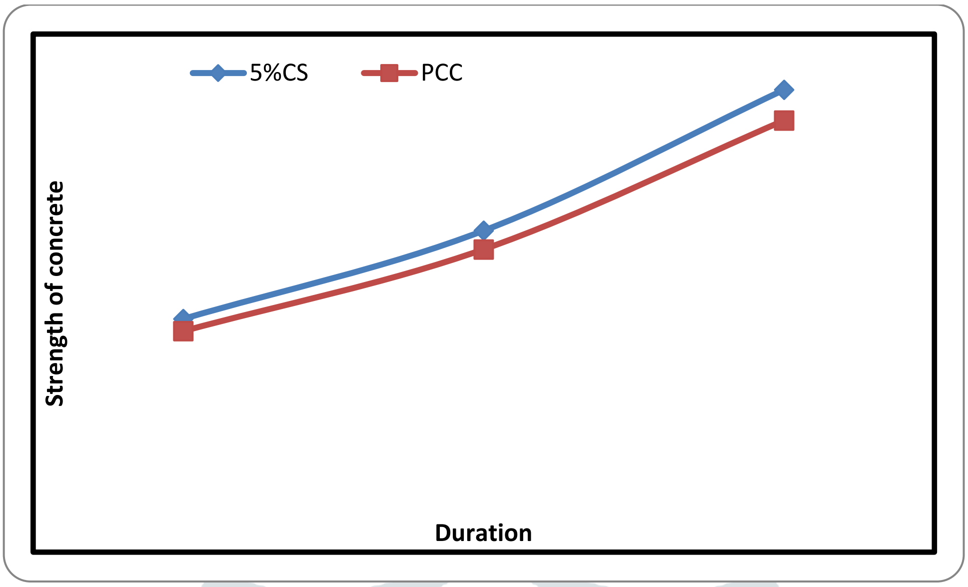

Figure 5. Strength result of 5% replacement by Copper Slag for Sand in Concrete.

After 3 days strength of P.C.C is nearly equal to concrete replacement by 5% Copper Slag. After 7 days strength of P.C.C is less than concrete replacement by 5% Copper Slag. After 28 days strength of P.C.C is less than concrete replacement by 5% Copper Slag.

Results of 20 % Replacement by Copper Slag for Various Durations

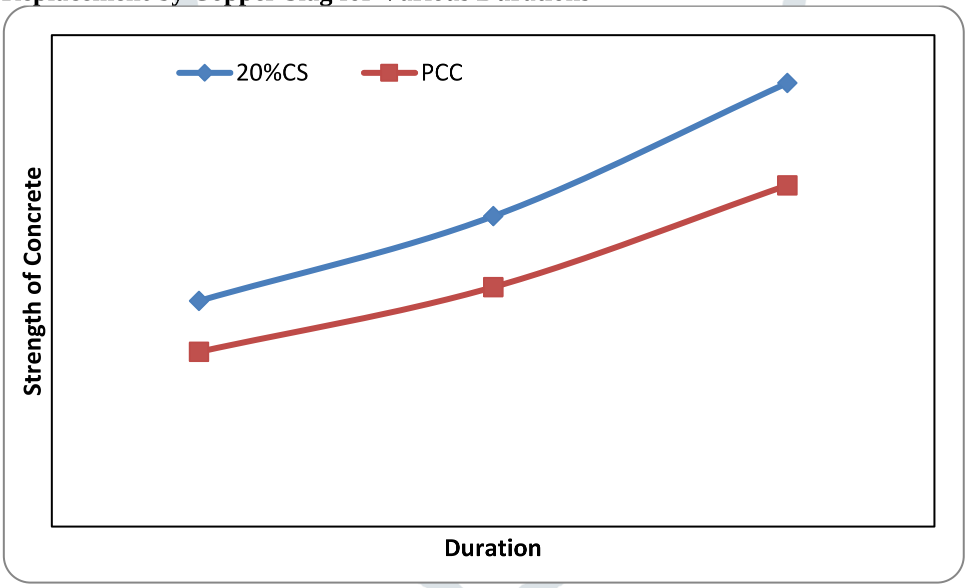

Figure 6. Strength result of 20% replacement by Copper Slag for Sand in Concrete.

After 3 days strength of P.C.C is very less than concrete replacement by 20% Copper Slag. After 7 days strength of P.C.C is very less than concrete replacement by 20% Copper Slag. After 28 days strength of P.C.C is very less than concrete replacement by 20% Copper Slag.

Table 4. Strength of the concrete by replacement of copper slag (28 days)

5% copper slag Replacement			
Area	Strength		Avg. Strength
	Load (KN)	Strength (N/mm^2)	
22500	1015.65	45.14	44.63
	1007.50	44.78	
	989.10	43.96	
10% copper slag Replacement			
22500	1130.20	50.23	49.81
	1115.10	49.56	
	1116.90	49.64	
15% copper slag Replacement			
22500	1187.10	52.76	52.14
	1160.10	51.56	
	1172.25	52.10	
20% copper slag Replacement			

22500	1234.58	54.87	54.15
	1214.55	53.98	
	1206.60	53.60	

Table 5 Strength behavior of PCC against other replacement materials for various durations.

Sr. no	Replacement levels (%)		Compressive Strength (MPa)		
	Fly Ash for Cement	Copper Slag for Sand	3 days	7 days	28 days
1	5	5	21.66	34.23	43.65
2	5	10	20.36	31.86	42.33
3	5	15	22.46	33.55	44.89
4	5	20	23.69	32.64	46.57
5	10	5	20.56	32.33	42.06
6	10	10	21.43	33.23	44.03
7	10	15	22.88	33.89	44.66
8	10	20	22.67	34.06	43.87
9	15	5	21.03	30.29	39.46
10	15	10	20.56	31.48	40.23
11	15	15	21.67	31.86	42.13
12	15	20	22.69	32.66	43.06
13	20	5	19.03	29.56	38.65
14	20	10	19.86	30.26	40.16
15	20	15	20.56	31.56	41.03
16	20	20	21.23	32.69	41.33

Effect of Nano material on the strength of Concrete

As the voids are present in the nano silica and micro silica due to which split tensile strength has been enhanced. The conventional concrete having split tensile strength 2.21 N/mm^2. Due to implementation of the nano silica and micro silica 2.83 N/mm^2 and 3.97 N/mm^2. Compressive Strength also increases by the application of nano material by 20.57 %. The convention concrete having compressive strength around 56.77 N/mm^2. By application of nano silica, and micro silica found to be 68.45 N/mm^2 and 70. 11N/mm^2.

CONCLUSION

From the research work following points can be concluded

The compressive strength for replacement by Fly Ash resulted such that only 5% FA shows better results after replacement but still lesser than OPC concrete which is 41.67N/mm^2. Similarly, when copper slag is replaced with find aggregates, results obtained shows that 20%CS shows the best results. From the above results it is clear that 5% FA and 20% CS showed the best results hence their combination was tested to evaluate the characteristics of blended concrete. From the combination 5% FA+ 20% CS results were obtained: 5%FA+ 20%CS=46.57N/mm^2. The best combination was found to be 5% FA+ 20% CS. The strength of concrete going to be enhanced by the increase in weight of copper slag. As per the duration the strength of the concrete is going to be varied when fly ash has been added in the preparation of concrete.

There is gradual increase in the strength of concrete when copper slag was applied in the manufacturing of concrete. Addition of Fly ash and copper slag will enhance the strength of concrete. And both can be replaced to cement and fine aggregate respectively. The optimum value of 5% fly ash and 20 % copper slag for sand. The strength of cube prepared of this combination having strength more than PCC.

Also, the durability tests shows that use of materials like coppers lag enhances the property of concrete and makes it more durable against resistive environments. By the application of 5 % nano silica and 5 % micro silica material in the preparation concrete enhance the flexural strength.

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