Experimental Investigation on Concrete Using Copper Slag as Fine Aggregate with Bacterial Admixture

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Abstract – "With increasing scarcity of river sand and natural aggregates across the country, construction sector is under tremendous pressure to explore alternative to these basic construction material to meeting growing demand of infrastructure demands,"In states like Kerala, Maharashtra and Gujarat, sand mining in rivers has already been banned owing to its disastrous impact on ecology. Therefore, slag has a big potential of being developed as a suitable alternative material to these resources. At present, across the world around 33 ton of slag is generated while in India three copper producers, Birla Copper and Hindustan Copper produce around 6-6.5 tones of slag at different sites.During the smelting operation, iron is removed as iron silicate, which is known commonly known as copper slag (Ferro sand).As per scientific estimate, for every ton of copper metal produced, around 1.8-2.2 tones of slag is generated. In this project tests on concrete is carried out by varying proportions of copper slag and bacteria. The test results show desirable properties such as increase in strength of concrete.

Index Terms – Copper Slag, Bacteria Concrete.

1. INTRODUCTION

In the present scenario carbon emission and sand mining are major concern due to its hazardous effect to environment and making serious imbalance to the ecosystem. Copper slag is one of the materials that can be considered as a waste material which could have a promising future in construction industry as partial or full substitute of any two either cement or aggregates. Copper slag is a by-product of copper extraction by smelting. During smelting, impurities become slag which floats on the molten metal.

Sterlite Industries India Ltd (SIIL) is planning to convert a waste product of its copper smelting plant at Tuticorin – copper slag — into an alternative material for concrete applications. The company has already started supplying the material to cement manufacturers and now wants to focus on road, abrasives and other industries. The Tuticorin plant of Sterlite has a capacity of 400,000 tons per annum and the company plans to double it with an investment of Rs 2,500 crore. The key raw material for copper smelter is copper concentrate which mainly consists of copper, iron and Sulphur.

During the smelting operation, iron is removed as iron silicate, which is known commonly known as copper slag (Ferro sand).As per scientific estimate, for every ton of copper metal produced, around 1.8-2.2 tons of slag is generated, Sterlite Industries India Ltd. "Therefore, slag has a big potential of getting developed as a suitable alternative material to these resources. It is a new business avenue for us and we are going to make revenue out of waste," At present, across the world around 33 ton of slag is generated while in India three copper producers Sterlite, Birla Copper and Hindustan Copper produce around 6-6.5 tons of slag at different sites.

1.1. Significance of using bacteria

In this technique bacteria from bacillus family are impregnated in concrete which have calcium as their food from concrete. When the bacteria get in contact with atmosphere they use water and carbon dioxide from surrounding environment produces the precipitate of calcium carbonate (lime stone). The pores in concrete gets reduced and filled with calcium carbonate.This ultimately seals the cracks and enhances compressive strength of concrete

1.2. Impregnation of bacteria

Bacillus subtilis is brought up in its full grown stage in concreting site in liquid / aqueous state. This aqueous stage bacterium is poured in water which will be used for concreting. The full grown stage lasts for 2 to 3 hours at room temperature. These bacteria should be impregnated in concrete in its full grown stage.

1.3. Advantages of bacterial concrete

- Self-repairing of cracks without any external aide.
- Significant increase in compressive strength and flexural strength when compared to normal concrete.
- Reduction in permeability of concrete.
- Reduces the corrosion of steel due to the cracks formation
- Bacillus bacteria are harmless to human life and hence it can be used effectively.

1.4. Limitations of bacterial concrete

- Cost of bacterial concrete is double than conventional concrete.
- Growth of bacteria is not good in any atmosphere and media.
- The clay pellets holding the self-healing agent comprise 20% of the volume of the concrete. This may become a shear zone or fault zone in the concrete.
- Design of mix concrete with bacteria here is not available any IS code or other code.
- Investigation of calcite precipitate is costly.

1.5. Copper Slag

Copper slag, a residue of copper extraction process more or less possesses the properties of copper upto some extent. But has not been utilized the maximum. Various researches have studied the mechanical properties, durability parameters of copper slag. From those results it can be said to have more strength over futile fine aggregate replacement such as fly ash or rice or even pumice.

2. LITERATURE REVIEW

Researchers studied and developed waste management strategies to apply for advantages ofspecific needs. Copper slag is obtained as waste product from the sterlite industriesOwing to the scarcity of fine aggregate for the preparation of mortar and concrete, partialreplacement of Copper Slag with sand have been attempted To understand the scope of existing research work carried on bacteria and copper slag, literature survey was carried out. The summary of reviews are as follows:

2.1. Copper slag as fine aggregate

Investigations were carried out to explore the possibility of using copper slag as a replacement of sand inconcrete mixtures. The effects of replacing fine aggregates bycopper slag on the compressive strength of cubes, split tensile strength of cylinders and flexural strength ofbeams are evaluated in this study. The water consumed by the copper slag during mixing is found to be very less as compared with river sand

2.2. Bacterial concrete

Different researches in the recent years on the use of bacterial concrete/bio-concrete for the enhancement in the durability, mechanical and permeation aspects of concrete have been carried out. It contains studies on different bacteria's, their isolation process, different approaches for addition of bacteria in concrete, their effects on compressive strength and water absorption properties of concrete.

3. FRESH CONCRETE TESTING

Fresh concete is a freshly mixed material which can be mould into any shape. The relative quantity of cement, fine aggregate, coarse aggregate and water mixed together control the properties of concrete in wet state. Workability is the ability of a fresh concrete mix to fill the form/mould properly with the desired vibration and without reducing the concrete quality. Workability depends on water content, aggregate, cementitious content and age. Raising the water content or adding chemical increases concrete workability. Excessive water leads to increase bleeding or segregation, with the resulting concrete having reduced quality.

3.1. Test for workability

Workability can be measured by the concrete slump test. The cone is placed with the wide end down onto level, non-absorptive surface.It is then filled in three layers of equal volume, with each layer being tamped with a steel rod to consolidate the layer. When the cone is lifted, the enclosed material slumps which is measured with scale and noted down.

3.2. Test for compressive strength

In most structural applications concrete is primarily employed to take compressive loads. Hence compressive strength test is carried out on cube moulds of standard size. The moulds are placed in testing machine and load applied gradually. When it begins to crack, the load at failure is noted down. The test is carried out on 7^{th} and 14^{th} day from casting.

4. RESULTS AND DISCUSSION

The slump test values indicate good workability on addition of bacteria and copper slag. Copper slag addition shows significant increase in compressive strength.

4.1. Slump test

The following tables and graphs shows the slump value and compressive strength test results obtained by varying percentage of copper slag and bacteria added with concrete.

S.No.	Percentage of Bacteria	Bacteria ml	Slump Value at 20% of Copperslag as Fine aggregate
1	0%	0 ml	75
2	3%	60 ml	87
3	6%	180ml	98

Table 1 Slump Value Result for 20% Copper Slag

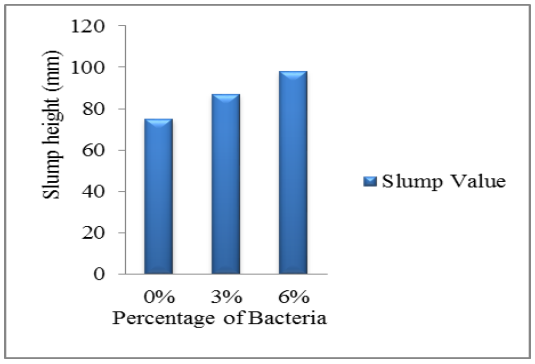

Figure 1 Slump Value Result 20% of Copper Slag

S.No.	Perecntage of Bacteria	Bacteria ml	Slump Value at 40% of Copperslag as Fine aggregate
1	0%	0 ml	70
2	3%	60 ml	80
3	6%	180ml	86

Table 2 Slump Value Result for 40% Copper Slag

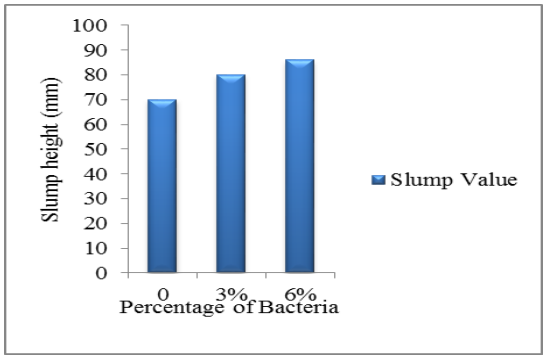

Figure 2 Slump Value Result for 40% Copper Slag

4.2. Compressive strength test

The following tables and graphs show the compressive strength test results obtained by varying percentage of copper slag and bacteria added with concrete.

S.No.	Bacteria		Replacement of Copper Slag	7 Days Curing	
	%	ml		Load (kN)	Compressive Strength (N/mm^2)
1	0	0	20%	200	8.88
2	3	60	20%	295	13.11
3	6	180	20%	325	14.44

Table 3 Compressive Strength of Concrete with 20% Copper Slag after 7 days Curing

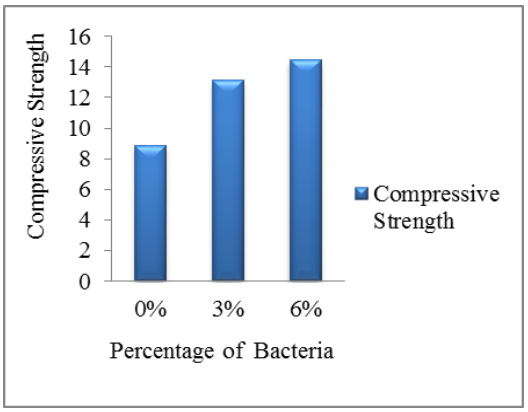

Figure 3 Compressive Strength of Concrete with 20% Copper Slag after 7 days Curing

S.No.	Bacteria		Replacement of Copper	7 Days Curing	
	%	ml		Load (kN)	Compressive strength (N/mm^2)
1	0	0	40%	395	17.55
2	3	60	40%	425	18.88
3	6	180	40%	475	21.11

Table 4 Compressive strength of concrete with 40% copper slag after 7 days curing

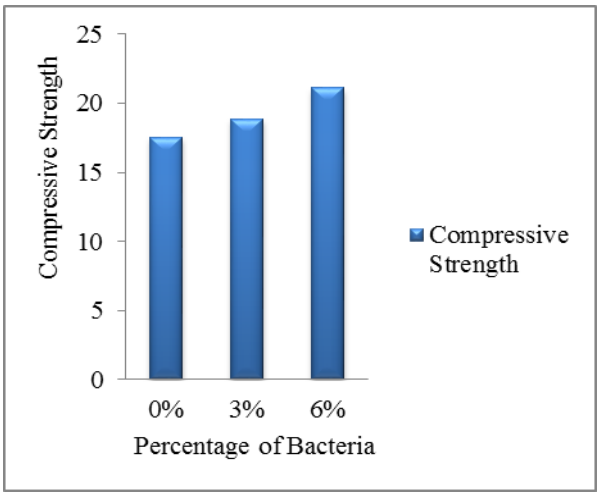

Figure 4 Compressive Strength of Concrete with 40% Copper Slag after 7 days Curing

S.No.	Bacteria		Replacement of Copper Slag	14 Days Curing	
	%	ml		Load (kN)	Compressive Strength (N/mm^2)
1	0	0	20%	450	20
2	3	60	20%	480	21.33
3	6	180	20%	550	24.44

Table 5 Compressive Strength of Concrete with 20% Copper Slag after 14 days Curing

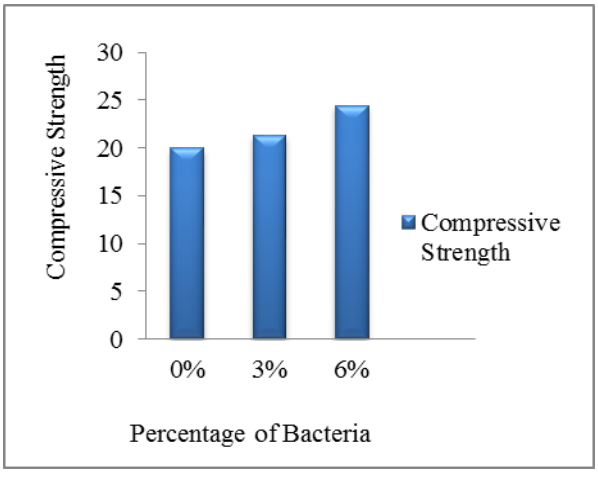

Figure 5 Compressive Strength of Concrete with 20% Copper Slag after 14 days Curing

S.No.	Bacteria		Replacement of Copper Slag	14 Days Curing	
	%	ml		Load (kN)	Compressive strength (N/mm^2)
1	0	0	40%	520	23.11
2	3	60	40%	550	24.44
3	6	180	40%	580	25.77

Table 6 Compressive Strength of Concrete with 40% Copper Slag after 14 days Curing

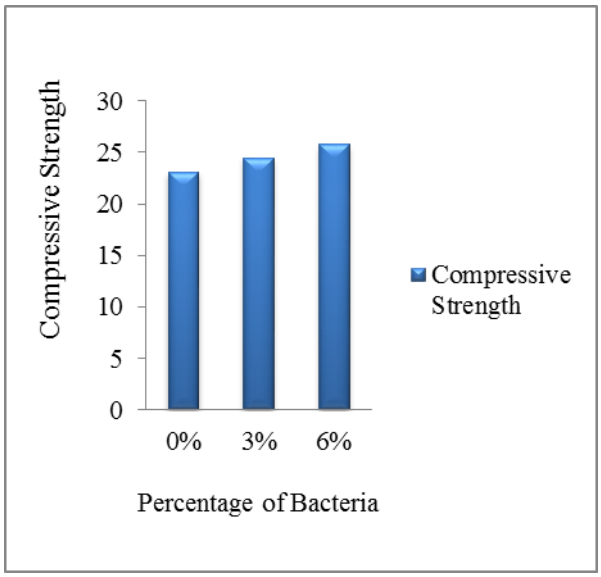

Figure 6 Compressive Strength of Concrete with 40% Copper Slag after 14 days Curing

5. CONCLUSION

Based on the experimental investigations, the following conclusions were drawn.

The compressive strength test indicate that the strength of concrete increases with respect to the percentage of copper slag added by the weight of fine aggregate. The results show approximately 40 to 50 % increse in strength of concrete.

The utilization of copper slag in concrete provides additional environmental as well as technical benefits for all related industries. Partial replacement of copper slag in fine aggregate and cement reduces the cost of making concrete.

The addition of bacteria also results in the increase of compressive strength the more amount of bacteria added it increases the value of compressive strength to more extent. In this study bacteria is added at rate of 0%, 3% and 6% to the weight of the cement. Results show that more amount of bacteria addition increases the workability of the concrete.

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