

# Copper Slag as Substitute for Fine Aggregate in Concrete

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**Abstract--** Copper slag is an industrial by-product produced during the process of manufacturing copper. About 2.2 tons of copper slag is generated, for every one ton of copper. In the present scenario as the demand for sand in the construction industry exceeds its availability, illegal sand mining has become a major concern which causes hazardous effects in the environment and ecological imbalance. One possible solution for this issue is to use industrial wastes as a replacement for fine aggregate in concrete which will in turn reduce the consumption of sand. There are also numerous other uses of copper slag other than acting as a replacing agent in concrete. Now a days, use of industrial waste materials has been encouraged in the construction field thereby reducing the consumption of natural resources. The use of copper slag in concrete offers a environmental benefits in addition to economic benefits specially in areas where a considerable amount of copper slag is being produced. The primary objective of this paper is to analyze the scope of using copper slag as alternative replacement material for sand in concrete.

**Keywords:** Copper slag, replacement of fine aggregate, application

## I. GENERAL

Sustainable development can be achieved by reconciling human needs and usage of natural resources as little as possible. It is also worth noting to return non degradable waste to the nature as little as possible. The construction industry in India is growing fast. The increase in the demand for homes and commercial space has driven the sector to a growth rate of 9.2 per cent every year, against the global average of 5.5 % Concerns have been raised over the way residential apartments and commercial buildings are designed and constructed. Most of these concerns pertain to energy, environment, sustainable construction methods and technology. The most common raw material used in construction is steel, cement, glass, aluminum, plastics, bricks, etc. All these are energy-intensive material are needed to be transported across vast distances leading to more energy consumption. It is not possible to meet the ever-growing demand for housing by using only traditional material like mud, thatch, timber, etc which are energy efficient. Hence a need for alternate materials is felt.

Also, it is important to realize that optimum utilization of the available energy resources and raw materials is vital. It is in this context that the eco-friendly construction material gain importance. In all the developing countries with increasing industrialization large amounts of by industrial waste is being generated and accumulated over years. Sustainability, efficiency and economy are most important issues in today's construction industry. Alternate waste materials produced from industries in large quantities meet all these three requirements. Considering the need and availability, utilization of secondary materials is being widely encouraged in construction field. In the manufacturing process of cement and concrete, large amount of energy is needed and many harmful gases are released. These harmful effects can be reduced by producing good and durable concrete by using Industrial by-products. Different types of slag according to the property can be utilized for different purposes. Copper slag is one such material which is an industrial waste product, and has a promising future in construction industry as substitute of either cement or aggregates.

## II. COPPER SLAG

Today, as a result of continuous growth in population the demand for housing and infra structure development also increased. With increasing urbanization and rapid industrialization, many new technologies evolved and most of these technologies are accompanied by generation of large amount of industrial waste. The excessive generation of waste resulted in discharge of pollutants into the atmosphere. These pollutants if utilized by recycling would contribute to a large extent in saving the mother earth.

Copper slag is one such industrial waste which is produced from the blast furnace as slag during copper metal extraction process. It is also a by-product of metallurgical operations in reverberatory furnaces. Copper slag was initially imported from Japan and was used as an abrasive material for removing rust and marine deposits by sandblasting. After repetitive recycling and reuse, the copper slag lost its original abrasive property was then disposed in landfills. However, there were concerns about the leaching of heavy metals into soil and ground-water causing pollution again.

Holcim Singapore found a novel way of utilizing this waste into concrete thereby not only removing the environmental concern but also finding a value-added and meaningful substitute for natural sand.

Copper slag is totally inert material and its physical properties are similar to natural sand. In the present days scenario, there is a acute scarcity of natural fine aggregate, and many constructions were halted due to lack of availability of fine aggregate. In recent years, consumption of fine aggregate has increased all over the world, with fast developments in the construction Industry. In order to reduce depletion of natural aggregate due to construction, other substitute materials can be used as alternatives.

Concrete is a mixture of cement, aggregate and water. Fine aggregate acts as a filler which constitutes of about 45 – 60 % of the total volume of concrete. Thus the focus of this paper is to utilize the copper slag by replacement for fine aggregate thus maintaining economy and increasing the strength of concrete. Currently, about 2600 tons of Copper slag is produced per day with a total accumulation of around 1.5 million tons. To produce every ton of copper, approximately 2.2–3.0 tons copper slag is generated as a by-product material. Utilization of copper slag in applications such as Portland cement substitution and/or as aggregates has threefold advantages of eliminating the costs of dumping, reducing the cost of concrete, and minimizing airpollution problems.

### *2.1 Need for utilization of copper slag in concrete*

The factors affecting the durability characteristics of concrete clearly points out to one major dependency, which is the permeability of concrete. Most of the factors influencing the durability of concrete suggest a control measure of lowering the permeability of concrete. It must be noted that the permeability of concrete is dependent on the water cement ratio, porosity and microstructure of concrete. Reducing the water cement ratio and by utilization of denser material will reduce the void ratio and improve the microstructure of concrete. With lower permeability the durability of concrete can be improved. Hence comes the role of copper slag.

The slag is a black glassy and granular in nature and has a similar particle size range like sand. The hardness of the slag lies between 6 and 7 in Mohs 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 free moisture content present in slag is less than 0.5%.

The specific gravity of slag lies between 3.3 and 3.98. The bulk density of granulated copper slag is varying between 1.8 to 2.15 g/ cc which is almost similar to the bulk density of conventional fine aggregate. These two properties results in production of concrete with higher density when used as sand substitution. Higher density means low porosity, low permeability and improved microstructure of concrete. Both copper slag and sand have similar particle size distribution. However, sand has higher fines content than copper slag.

The free lime content of Copper slag is very low which indicates that copper slag is not highly chemically reactive material and can be used as replacement material.

The water absorption for copper slag was 0.63% while it is 1.12% for sand. The free water content in copper slag concrete matrix increases as the copper slag content increases. This consequently results in increase in the workability of the copper slag concrete. Thus, it is obvious that copper slag concrete demand less water than the conventional concrete mix.

To date no major research has been conducted over the durability assessment of concrete with copper slag as partial replacement to fine aggregate. Since concrete durability depends on the surrounding environmental conditions, an on-site durability assessment would be more prolific to suit the site requirements. It is to be noted the tests to assess durability must be quick and yield reliable results.

Several Non-destructive test methods have been done throughout the past decade to assess the durability of concrete. The test results reproduce information which can be related to the durability characteristics of concrete. However a more advanced and yet simple test methods are needed to quantify the durability of concrete on-site.

### *2.2 Applications of copper slag*

Copper slag can be used

1. In building industry for use as a fill material.
2. As a substitute for sand in concrete construction.
3. In making building blocks.
4. in the sand blasting industry
5. In the manufacture of abrasive tools.
6. as an abrasive media to remove rust, old coating and other impurities in dry abrasive blasting due to its high hardness.



**Fig 1 Copper slag**

### 2.3 Copper Companies in India

The copper industry in India takes up about three percent of the entire world market for copper. Three copper companies in India – Sterlite Industries, Hindalco, and Hindustan Copper have contributed to India's transformation in market status .

The largest producer of copper in India is Sterlite Industries Ltd., Tuticorin, which has undoubtedly made a global impact in the copper industry. The Tuticorin plant of Sterlite has a capacity of 400,000 tonnes per annum and the company plans to double it with an investment of Rs 2,500 crore. [12]. The slag thus produced is highly stable and non-leachable in nature. The utility of copper slag as alternative material for other industrial/sectoral application has been vastly explored in the last one decade. The amount of slag estimated to be produced all over the world is around 33 million tonnes at the end of the year 2017. Out of the total quantity of slag produced only about 15-20% is used. [13]. Hence the remaining slag is disposed which causes harm to the environment.

### III. CONCLUSION

The study shows that the disposal of industrial wastes such as copper slag is now an environmental threat instead the material has found its use in the construction industry as a replacement for fine aggregate in concrete.

With increase in scarcity of river sand the requirement of finding an alternative has become a need of the hour. The above analysis revealed that using copper slag in concrete is suitable and improves the behavior of concrete.

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