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Reuse of Industrial Waste (Copper Slag) As Fine Aggregate In Concrete

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Abstract: This project reports the effect of concrete using copper slag as fine aggregate replacement. In this project work, the concrete grade M40 was selected and IS method was used for mix design. The properties of material for cement, fine aggregate, coarse aggregate and copper slag were studied for mix design. The various strength of concrete like compressive, flexural and split tensile 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, 14 and 28 days. The split tensile strength and the flexural strength were also obtained higher strength at 40% replacement level at 28 days.

Keywords:-Copper slag, Concrete, particle size distribution, Compressive strength; Split tensile strength; Flexural strength.

Introduction

Concrete is the most commonly used construction material, and the demand for it will increase as the demand for infrastructure development increases. Unfortunately, Ordinary Portland Cement (OPC) production depletes significant amounts of natural resources as it is a high energy-intensive construction material to produce, third only after the production of steel and aluminum. Furthermore, natural aggregate constitutes a substantial portion of traditional concrete. The natural source of coarse aggregate is crushed rock; and fine aggregate is naturally extracted from sand quarries.

Concrete is a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregate. In hydraulic cement concrete, the binder is formed from a mixture of hydraulic cement and water.

Different properties of concrete such as Grades of concrete(M20, M25, M30 etc),Compressive strength of concrete, Characteristic Strength of concrete, Tensile strength of concrete, Durability of concrete, Creep in concrete Shrinkage of concrete, Unit weight of concrete, Modular Ratio of concrete, Poisson's ratio of concrete.

Copper slag is an irregular, black, glassy and granular in nature and its properties are similar to the river sand. In this project Copper slag is an industrial by-product material produced from the process of manufacturing copper. Copper slag is a by-product obtained during the matte smelting and refining of copper. The major constituent of a smelting charge are sulphides and oxides of iron and copper. The charge also contains oxides such as SiO2, Al2O3, CaO and MgO which are either present in original concentrate or added as flux. It is Iron, Copper, Sulphur, Oxygen and their oxides which largely control the chemistry and physical constitution of smelting system. For every ton of copper production, about 2.2 tones of copper slag is generated. the chemical traces such as copper, sulphate and alumina present in the slag are not harmful.

Copper slag is used in the concrete as one of the alternative materials. The safe disposal of this waste is a lack, costly and causes environmental pollution. The construction industry is the only area where the safe use of waste material (copper slag) is possible. When it is introduced in concrete as a replacement material, it reduces the environmental pollution, space problem and also reduces the cost of concrete.

However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix. Mixes with 80% and 100% copper slag replacement gave the lowest compressive strength value of approximately 80 MPa, which is almost 16% lower than the strength of the control mix. The results also demonstrated that the surface water absorption decreased as copper slag quantity increases up to 40% replacement; beyond that level of replacement, the absorption rate increases rapidly.

Materials

Materials are used in concrete such as port-land Cement, Natural sand, Copper slag, Coarse aggregate and Water.

Portland cement is produced by mixing ground limestone, clay or shale, sand and iron ore. This mixture is heated in a rotary kiln to temperatures as high as 1,600 degrees Celsius. The raw ingredients of Portland cement are iron ore, lime, alumina and silica. These are ground up and fired in a kiln to produce a clinker. After cooling, the clinker is very finery ground. Cement is a finely pulverized, dry, material that by itself is not a binder but develops the binding property as a result of hydration.

Natural Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. River sand is one of the world's most plentiful resources (perhaps as much as 20% of the Earth's crust is sand) and has the ability to replenish itself. River sand is vital for human well-being & for sustenance of rivers.

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Coarse aggregates are components found in many areas of the construction industry. They have structural uses such as a base layer or drainage layer below pavements and in mixtures like asphalt and concrete. maximum size of aggregate is the standard sieve size (40mm, 25mm, 20mm, 12.5mm, 10mm)

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through which at least 90% of coarse aggregate will pass. Maximum size of aggregate affects the workability and strength of concrete.

Water employed in the mixtures was taken from the Indus institute of engineering technology, concrete laboratory which is tap water. This water was also used in the curing tanks.

Methodology

Each mix underwent a series of tests. These tests were chosen to assess the individual characteristic of the aggregates as well as the workability, strength and durability indicators of the concrete. A complete list of the tests is given below particle size distribution test, sieve analysis, water absorption test, slump test, compressive strength test, split tensile strength test, flexural strength test.

Illustration

A mix design for M40 grade of concrete, having moderate workability (Slump range 25mm to 50mm)

Cement:-53 grade (Although, actual 28 days compressive strength = 53 N/mm²)

Fine aggregate:-FM of natural sand = 2.68.FM of copper slag = 3.47.Specific gravity for natural sand = 2.74, Specific gravity for copper slag = 3.56

Coarse aggregate:-20mm - Specific gravity 2.75

Experiment work:

Particle size distributions were carried out for all fine and coarse aggregates used in this project in accordance with IS 383-1970, Specification for Coarse and Fine Aggregate from Natural Sources for Concrete.

Specific gravity test is used for finding the specific gravity. It is carried out by pycnometer tube.

W1= Weight of the empty clean and dry pycnometer, W2= Weight of the pycnometer containing the dry soil, W3= Weight of the pycnometer, soil and water, W4= Weight of the pycnometer and distilled water;

Formula used in specific gravity = $\frac{W2-W1}{(W2-W1)-(W3-W4)}$

Water absorption test is carried out by

Water Absorption (% of dry weight) = $\frac{100(A-B)}{B}$

Where; A = weight in g of saturated surface-dry sample and B = weight in g of oven-dried sample.

Slump cone test is a measure of the behavior of a compacted inverted cone of concrete under the action of gravity as per IS 1199. It measures the consistency or the wetness of concrete.

Compacting factor test of fresh concrete is done to determine the workability of fresh concrete by compacting factor test as per IS 1199. The apparatus used is Compacting factor apparatus.

Compressive strength is often measured on a universal testing machine. By definition, the ultimate compressive strength of a material is that value of uni-axial compressive stress reached when the material fails completely.

Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking.

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

Result & Discussion

- **Physical Properties:-**

Table:-1, Physical Characteristics of Fine Aggregates

Parameters	Specific gravity
Natural sand	2.74
copper slag	3.56

- **Water Absorption of aggregates:-**

Table:-2, Water Absorption of Fine Aggregates (%)

Property	Natural sand	Copper slag	Method
Water absorption	.78	0.40	IS

- **Sieve Analysis and Fineness Modulus:-**

Table:-3, Fineness Modulus for Various Fine Aggregates

Property	Natural sand	Copper slag	Method
Fineness Modulus	2.68	3.47	Calculation

- **Slump value**:- slump value increased with the percentage of copper slag increases in concrete.
- **Compacting factor**:- The value of compacting factor slightly increased with the replacement of copper slag in concrete. The calculated value of compacting factor was 0.82 for the control mixture whereas 0.96 with the 100% replacement of copper slag. This is mainly due to the higher specific gravity of copper slag which was 3.56 compared with sand which has a specific gravity of 2.74.
- **Compressive strength**:- The compressive strength of cube was found to be 32 N/mm2 at 0% fine aggregate replacement and of 31 N/mm2 at 100% fine aggregate replacement of 7 days. And the compressive strength of cube at 28 days was found to be 36 N/mm2 at 0% fine aggregate replacement and of 35.5N/mm2 at 100% fine aggregate replacement. The maximum compressive strength was found to be at 40% fine aggregate replacement of about 43.5N/mm2 at 7 days and of 48.5 N/mm2at 28 days The compressive strength of concrete at 7 and 28 days increased gradually up to 40% fine aggregate replacement and then decreased with increase in percentage of replacement.
- **Split tensile strength**:- The split tensile strength of cylinder was found to be 2.45 N/mm2 at 0% fine aggregate replacement and of 1.85 N/mm2 at 100% fine aggregate

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replacement. The maximum split tensile strength was found to be at 40% fine aggregate replacement of about 3.09 N/mm2. The split tensile strength of copper slag added concrete was gradually increased up to 40% replacement and then decreased with further fine aggregate replacement.

- **Flexural strength**:- The maximum flexural strength of beam was found to be at 40% fine aggregate replacement of about 7.73 N/mm2. The flexural strength of beam showed higher strength at 40% fine aggregate replacement.

Conclusions:

From the results and discussions, the following conclusions were made

• The workability of concrete increased with the increase in copper slag content of fine aggregate replacements at same water-cement ratio.

• Form the results of compressive strength, split tensile strength and flexural strength, the concrete shown higher value at 40% replacement of fine aggregate using copper slag. So it is recommended that 40% of fine aggregate can be replaced by copper slag.

• The replacement of fine aggregate using copper slag in concrete re-duce the construction cost due to saving in material cost.

• The replacement of fine aggregate using copper slag in concrete re-duce the environmental impact due to quarrying & aggregate mining.

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