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UTILIZATION OF COPPER SLAG TO IMPROVE THE PROPERTIES OF M20 CONCRETE : A REVIEW

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Abstract: The poor and unsatisfactory performance of conventional concrete under aggressive environmental conditions has necessitated the researchers and engineers to look for new concrete composites. For many years, by-products such as fly ash, silica fume and slag were considered as waste materials. Concrete prepared with such materials showed improvement in workability and durability compared to normal concrete. Copper slag is an industrial by-product material produced from the process of manufacturing copper. Copper slag possesses mechanical and chemical characteristics that qualify the material to be used in concrete as a partial replacement for Portland cement or as a substitute for aggregates. Various mix proportions of concrete were prepared by the addition of Copper Slag in different proportions. Different properties of concrete e.g. compressive strength, Flexural strength and Split tensile strength at 7 & 28 days have been studied.
Keywords: Copper Slag, Compressive Strength, Flexural Strength and Split Tensile Strength.

I. INTRODUCTION

The utilization of industrial waste or secondary materials has encouraged the production of cement and concrete in construction field. New by-products and waste materials are being generated by various industries. Dumping or disposal of waste materials causes environmental and health problems. Therefore, recycling of waste materials is a great potential in concrete industry. For many years, by-products such as fly ash, silica fume and slag were considered as waste materials. Concrete prepared with such materials showed improvement in workability and durability compared to normal concrete and has been used in the construction of power, chemical plants and under-water structures. Copper slag is an industrial by-product material produced from the process of manufacturing copper. For every ton of copper production, about 2.2 tones of copper slag is generated. It has been estimated that approximately 24.6 million tons of slag are generated from the world copper industry (Gorai et al 2003). Although copper slag is widely used in the sand blasting industry and in the manufacturing of abrasive tools, the remainder is disposed of without any further reuse or reclamation. Copper slag possesses mechanical and chemical characteristics that qualify the material to be used in concrete as a partial replacement for Portland cement or as a substitute for aggregates. For example, copper slag has a number of favorable mechanical properties for aggregate use such as excellent soundness characteristics, good abrasion resistance and good stability reported by (Gorai et al 2003). Copper slag also exhibits pozzolanic properties since it contains low CaO. further investigations are necessary in order to obtain a comprehensive understanding that would provide an engineering base to allow the use of copper slag in concrete.

II. COPPER SLAG

Copper slag is a by-product obtained during the matte smelting and refining of copper has been reported by Biswas and Davenport (2002). The major constituent of a smelting charge are sulphides and oxides of iron and copper. The charge also contains oxides such as SiO_2, Al_2O_3 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. A further important factor is the oxidation/reduction potential of the gases which are used to heat and melt the charge stated by Gorai et al (2002). As a result of this process copper- rich matte (sulphides) and copper slag (oxides) are formed as two separate liquid phases. The addition of silica during smelting process forms strongly bonded silicate anions by combining with the oxides.

III. APPLICATIONS OF COPPER SLAG

Copper slag is mainly used for surface blast-cleaning. Abrasive blasting is used to clean and shape the surface of metal, stone, concrete and other materials. In this process, a stream of abrasive grains called grit is propelled toward the work piece. Copper slag can be used in concrete production as a partial replacement for sand. Copper slag is used as a building material, formed into blocks. Such use was common in areas where smelting was done, The granulated slag (<3 mm size fraction) has both insulating and drainage properties which are usable to avoid ground frost in winter which in turn prevents pavement cracks. The usage of this slag reduces the usage of primary materials as well as reduces the construction depth which in turn reduces energy demand in building.

IV. PROPERTIES OF COPPER SLAG

Lighter weight: With Copper Slag, concrete can be cast in thinner sections and is therefore as much as 75% lighter than similar pieces cast with traditional concrete.
Reinforcement: Since Copper Slag is reinforced internally, there is no need for other kinds of reinforcement, which can be difficult to place into complex shapes
Toughness: Copper Slag doesn’t crack easily—it can be cut without chipping.
Surface finish: Because it is sprayed on, the surface has no bug holes or voids.

Sustainable: Because it uses less cement than equivalent concrete and also often uses significant quantities of recycled materials (as a pozzolana), Copper Slag qualifies as sustainable.

V. LITERATURE REVIEW

As we know the properties of concrete gets improved due to the incorporation of Copper Slag. Large no. of papers have being published which tells about the compressive strength, flexural strength and split tensile strength of concrete according to their opinion.

R R Chavan et al [1] reports on an experimental program to investigate the effect of using copper slag as a replacement of fine aggregate on the strength properties. Copper slag is the waste material of matte smelting and refining of copper such that each ton of copper generates approximately 2.5 tons of copper slag. Copper slag is one of the materials that is considered as a waste which could have a promising future in construction Industry as partial or full substitute of aggregates.

T.Ch.Madhavi et al [2] presents the effect of copper slag when included in concrete as a replacement material for sand. It focuses on the effect of copper slag on behaviour of concrete. This paper outlines the properties, preparation and testing and finally the results obtained from experimental investigations using copper slag which is a waste by product produced during the smelting process of manufacture of concrete from its ore. Experimental investigations are carried out by replacing sand with copper slag in content of 10%, 20%, 30%, 40%, 50%, 60% and 100% keeping all other ingredients constant. It is observed that the optimum content of copper slag that can be used as replacement material is 40% beyond which the strength starts decreasing

M. V. Patil et al [3], described the introduction and production of copper slag and its various applications in construction industry. In this paper, the author aimed at the greatest potential applications for using copper slag is in concrete production. This research work by author is concerned with the experimental investigation on strength of concrete and optimum percentage of the partial replacement by replacing fine aggregate via 0%, 10%, 20%, 30%, 40% of copper slag. In this paper, properties of copper slag concrete and its comparison with the conventional concrete are also mentioned. Future recommendations about copper slag concrete are also included.

Al-Jabri et al [4] investigated the effect of using copper slag as a fine aggregate on the properties of cement mortars and concrete. Various mortar and concrete mixtures were prepared with different proportions of copper slag ranging from 0% (for the control mixture) to 100% as fine aggregates replacement. Cement mortar mixtures were evaluated for compressive strength, whereas concrete mixtures were evaluated for workability, density, compressive strength, tensile strength, flexural strength and durability.

Wei wu et al [5] investigated the mechanical properties of high strength concrete incorporating copper slag as fine aggregate. The workability and strength characteristics were assessed through a series of tests on six different mixing proportions at 20% incremental copper slag by weight replacement of sand from 0% to 100%. A high range water reducing admixture was incorporated to achieve adequate workability.

Al-Jabri et al [6] has investigated the performance of high strength concrete (HSC) made with copper slag as a fine aggregate at constant workability and studied the effect of super plasticizer addition on the properties of HSC made with copper slag. Two series of concrete mixtures were prepared with different proportions of copper slag.

Al-Jabri et al [7] has investigated the effect of using copper slag as a replacement of sand on the properties of high performance concrete (HPC). Eight concrete mixtures were prepared with different proportions of copper slag ranging from 0% (for the control mix) to 100%. Concrete mixes were evaluated for workability, density, compressive strength, tensile strength, flexural strength and durability.

Isa Yuksel and Turhan Bilir et al [8] presented the results of research aimed at studying the possible usage of bottom ash (BA) and granulated blast-furnace slag (GBFS) in production of plain concrete elements. Sufficient number of briquettes, paving blocks and kerbs specimens containing GBFS and BA as fine aggregate replacement were produced in laboratory. Then, a few tests were conducted for investigating durability and mechanical properties of these specimens. Unit weight, compression strength and freeze-thaw tests were conducted for briquette specimens.

Ramazan Demirbog and Rustem Gul et al [9] investigated the use of Blast furnace slag aggregates (BFSA) to produce high-strength concretes (HSC). These concretes were made with total cementitious material content of 460-610 kg/m3. Different water/cement ratios (0.30, 0.35, 0.40, 0.45 and 0.50) were used to carry out 7- and 28-day compressive strength and other properties. Silica fume and super plasticizer were used to improve BFSA concretes. Slump was kept constant throughout this study. Ten percent silica fume was added as a replacement for ordinary Portland cement (OPC) in order to obtain HSC.

Teik-Thye Lim and Chu et al [10] conducted a study on the feasibility of using spent copper slag as fill material in land reclamation. The physical and geotechnical properties of the spent copper slag were first assessed by laboratory tests, including hydraulic conductivity and shear strength tests. The physical and geotechnical properties were compared with those of conventional fill materials such as sands.

Byung Sik Chun et al [11] conducted several laboratory tests and evaluated the applicability of copper slag as a substitute for sand of sand compaction pile method.. From the mechanical property test, the characteristics of the sand and copper slag were compared and analyzed, and from laboratory model test, the strength of composite ground was compared and analyzed by monitoring the stress and ground settlement of clay, sand compaction pile and copper slag compaction pile.

VI. MATERIALS USED

Materials required for making Samples essentially consist of cement, fine sand, coarse aggregates and Copper Slag. These materials are described below-

CEMENT : Ordinary Portland cement is used in this

experimental work as per IS 4031-1988.
FINE AGGREGATES: Locally available river sand passed through 4.75mm IS sieve has been used in the preparation of Sample. It confirms to IS 383-1970 which comes under Zone.
COARSE AGGREGATES: The Coarse aggregate are obtained from a local quarry has been used. In this experimental work coarse gravel of 20mm and crushed aggregate of 10mm are mixed in 60:40.
COPPER SLAG:- Copper slag is a by-product material produced from the process of manufacturing copper. As the copper settles down in the smelter, it has a higher density, impurities stay in the top layer and then are transported to a water basin with a low temperature for solidification. The end product is a solid, hard material that goes to the crusher for further processing.
WATER: - Water used for mixing and curing was clean and free from injurious amounts of oils, acids, alkalis, salts and sugar, organic substances that may be deleterious to concrete. As per IS 456- 2000 Potable water is generally considered satisfactory for mixing and curing of concrete. Accordingly, potable tap water was used for the preparation of all concrete specimens.

VII. METHODLOGY

CONSISTENCY TEST: This is a test to estimate the quantity of mixing water to form a paste of normal consistency defined as that percentage water requirement of the cement paste, the viscosity of which will be such that the Vicat's plunger penetrates up to a point 5 to 7 mm from the bottom of the Vicat's mould.
INITIAL AND FINAL SETTING TIME:-The initial setting time may be defined as the time taken by the paste to stiffen to such an extent that the Vicat's needle is not permitted to move down through the paste to within 5 ± 0.5 mm measured from the bottom of the mould. The final setting time is the time after which the paste becomes so hard that the angular attachment to the needle, under standard weight, fails to leave any mark on the hardened concrete. Initial and final setting times are the rheological properties of cement
SOUNDNESS TEST: It is essential that the cement concrete does not undergo large change in volume after setting. This is ensured by limiting the quantities of free lime and magnesia which slake slowly causing change in volume of cement (known as unsound). Soundness of cement may be tested by Le Chatelier method or by autoclave method. For OPC, RHC, LHC and PPC it is limited to 10 mm, whereas for HAC and SSC it should not exceed 5 mm.
COMPRESSIVE STRENGTH: The compression test shows the compressive strength of hardened concrete. The compression test shows the best possible strength concrete can reach in perfect conditions. The compression test measures concrete strength in the hardened state. Testing should always be done carefully. Wrong test results can be costly. The testing is done in a laboratory off-site. The only work done on-site is to make a concrete cylinder for the compression test. The strength is measured in Megapascals (MPa) and is commonly specified as a characteristic strength of concrete measured at 28 days after mixing. The compressive strength is a measure of the concrete's ability to resist loads which tend to crush it.

Procedure for compression test of concrete:-

- Clean the cylinder mould and coat the inside lightly with form oil, then place on a clean, level and firm surface, ie the steel plate. Collect a sample.
- Fill 1/2 the volume of the mould with concrete then compact by rodding 25 times. Cylinders may also be compacted by vibrating using a vibrating table.
- Fill the cone to overflowing and rod 25 times into the top of the first layer, then top up the mould till overflowing.
- Level off the top with the steel float and clean any concrete from around the mould.
- Cap, clearly tag the cylinder and put it in a cool dry place to set for at least 24 hours.
- After the mould is removed the cylinder is sent to the laboratory where it is cured and crushed to test compressive strength.

SPLIT TENSILE STRENGTH TEST
The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

Procedure of Splitting Tensile Test:

- Take the wet specimen from water after 7 days of curing
- Wipe out water from the surface of specimen
- Draw diametrical lines on the two ends of the specimen to ensure that they are on the same axial place.
- Note the weight and dimension of the specimen.
- Set the compression testing machine for the required range.
- Keep are plywood strip on the lower plate and place the specimen.
- Align the specimen so that the lines marked on the ends are vertical and centered over the bottom plate.
- Place the other plywood strip above the specimen.
- Bring down the upper plate to touch the plywood strip.
- Apply the load continuously without shock at a rate of approximately 14-21kg/cm2/minute (Which corresponds to a total load of 9900kg/minute to 14850kg/minute)
- Note down the breaking load(P)

FLEXURE STRENGTH TEST
Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 6 x 6 inch (150 x 150-mm) concrete beams with a span length at least three times the depth. The flexural strength is expressed

as Modulus of Rupture (MR) in psi (MPa) and is determined by standard test methods ASTM C 78 (third-point loading) or ASTM C 293 (center-point loading).Flexural Strength of Concrete Flexural MR is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design. The MR determined by third-point loading is lower than the MR determined by center-point loading, sometimes by as much as 15%.
The flexural strength was calculated as follows.
Flexural strength (MPa) = $(P \times L) / (b \times d^2)$,
Where, P = Failure load, L = Centre to centre distance between the support = 640 mm, b = width of specimen=150 mm, d = depth of specimen= 150 mm.

VIII. OBJECTIVE

- To Find the M20 concrete properties due to addition of Copper Slag.
- To Study the comparison between the compressive strength of plain concrete and Concrete Containing Copper Slag.
- To Study the comparison between the Flexural strength of plain concrete and Concrete Containing Copper Slag.
- To Study the comparison between the Split Tensile strength of plain concrete and Concrete Containing Copper Slag.
- To Find the economical mix of Concrete Containing Copper Slag.
- To Find the workability of Concrete Containing Copper Slag.

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