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Investigation of Mechanical Properties of Concrete by Partially Replacing Cement with Silica Fume and Fine Aggregate with Copper Slag

SUNKESULA VIJAY KUMAR[1], PARSINENI BALAKRISHNA[2]

[1]PG Scholar, Department of civil Engineering, Newton's Institute of Science and Technology, Macherla, Guntur, AP, India.

[2]Assistant Professor, Department of Civil Engineering, Newton's Institute of Science and Technology, Macherla, Guntur, AP, India.

Abstract: Copper slag is a by-product obtained during the matte smelting and refining of copper. Current options of management of this slag are recycling, recovering of metal, production of value added products and disposal in slag dumps or stockpiles. This paper presents the results of a study undertaken to investigate the feasibility of using copper slag as fine aggregates in concrete. The effects of replacing coarse aggregate by copper slag on the compressive strength, split tensile strength, flexural strength performance of concrete containing different percentage of silica fume as a partial replacement of cement and Copper slag with fine aggregates. The silica fume in concrete is replaced accordingly with the percentage of 5%, 7.5%, 15%, 17.5% and 20% by weight of cement and 5%, 10%, 15%, 20% and 25% of –Copper slag is added by weight of fine aggregate. Concrete cubes, cylinders and beams are tested at the age of 3, 7 and 28 days of curing. Finally the strength performance of silica fume based copper slag concrete is compared with the performance of conventional concrete.

Keywords: silica fume, copper slag, compressive strength, split tensile strength, flexural strength

1. INTRODUCTION

The amount and type of generated waste has grown as the world population increases. Numerous waste materials result from manufacturing, sewage treatment plants, industries, households, and mining. While the volume of waste is continuing to grow, approval for facilities that provide proper disposal is becoming more difficult to obtain. Copper slag is a by-product obtained during matte smelting and refining of copper. One of the greatest potential applications for reusing copper slag is in cement and concrete production. The use of copper slag in cement and concrete provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of copper slag is produced. Out of the total cost of construction, building materials contribute to about 70% of cost in developing countries like India. Therefore, the need of the hour is replacement of costly and scarce conventional building materials by innovative, cost effective and environment– friendly alternate building materials. The new material should be environment–friendly and preferably utilize industrial wastes generated as a result of rapid industrialization. concrete is widely used construction material for various types of structures due to its durability. Natural resources are depleting worldwide while at the same time the generated wastes from the industry are increasing substantially.

1.1 SILICA FUME

An experimental investigation is achieved to examine the behavior of concrete by way of changing the cement with silica fume. It involves a sure tests to locate the fine improvement of concrete whilst silica fume is added to it.
Silica fume, additionally referred as micro silica or condensed silica flume, is any other material that is used as artificial mineral admixtures
Silica fume as an admixture has opened a brand new development in concrete era. The utilization of first-rate plasticizer with silica fume has been the backbone of present day excessive overall performance concrete. It need to be mentioned that silica fume via itself, doesn't make a contribution to electricity. However it produces the belongings of electricity being first-class pozzolanic cloth. Silica fume enables in reduction of water will become viable in presence of excessive dosage of exquisite plasticizer and dense packing of cement paste..

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1.2 COPPER SLAG

Many countries are witnessing a rapid growth in the construction industry, which involves the use of natural resources for the development of infrastructure. The authors developed waste management strategies to apply for replacement of fine aggregate for specific need. The construction industry is the only area where the safe use of waste material (Copper Slag) is possible, Copper Slag reduces environment pollution, space problem and also reduces the cost of concrete. Copper Slag were generated as a by-product of Copper processing ,in which mostly ended up as land fill though some amount of Copper Slag are used in the application of abrasives in the process of rust removal. It contains large amount of Iron Oxide and Silicate. Its physical properties are similar of natural sand. The chemical traces such as Copper, Sulphate & Alumina present in the Slag are not harmful. Copper slag is the waste material of refining of copper and matte smelting such that each ton of copper generates approximately 2.5 tons of copper slag. Copper slag is one of the materials that are considered as a waste which could have a promising future in construction Industry as partial or full substitute of aggregates. Copper Slag is used to increase the strength of concrete and reduces the environmental pollution, space problem and also reduces the cost of concrete. Copper slag has also gained popularity in the building industry for use as a fill material. Contractors may also use copper slag in place of sand during concrete construction. Copper slag can also be used as a building material, formed into blocks. Copper slag is widely used in the sand blasting industry and also in the manufacture of abrasive tools..

2. LITERATURE REVIEW

Kumar & Dhaka (2016) write a Review paper on partial replacement of cement with silica fume and its effects on concrete residences. The important parameter investigated on this examine M-35 concrete blend with partial replacement by silica fume with various zero, five, nine, 12 and 15% with the aid of weight of cement The paper offers a detailed experimental observe on compressive strength, flexural electricity and cut up tensile electricity for 7 days and 28 days respectively. The results of experimental investigation suggest that the use of silica fume in concrete has elevated the energy and sturdiness at all ages whilst compared to normal concrete has elevated the strength and sturdiness at all ages when compared to ordinary concrete

Alok (2016) write A Research Paper on Partial Replacement of Cement in M-30 Concrete from Silica Fume and Fly Ash. Replacement degrees of OPC by means of Silica Fume had been zero%, 2.5%, 5p.Cand seven.Five% wherein substitute levels of Ordinary Portland cement through Fly Ash had been 0%, five%, 10% and 15% through weight. 1% fantastic-plasticizer become utilized in all of the test specimens for higher workability at decrease water cement ratio and to perceive the pointy results of Silica Fume and Fly Ash at the houses of concrete. Water-cement ratio turned into stored zero.43 in all cases.Forty three.1 N/mm2 turned into the most compressive energy which become received at alternative degree of 7.5% via weight of SF and 20% by means of weight of FA with cement.6.47 N/mm2 became the most flexural electricity which became acquired at replacement stage of 7.5% by means of weight of SF and 20% through weight of FA with cement.2.573 N/mm2 changed into the most split tensile power which become acquired at substitute degree of seven.Five% by using weight of SF and 20% by weight of FA with cement.

S. Geetha et al. (2017) investigated on high performance concrete with copper slag for marine environment. Properties of cement containing copper slag, fly ash and silica fumes found more better than normal mic concrete. Copper slag has a wide application in marine construction work as it improves the compressive strength, flexural strength and reduction in sorptivity.

3. MATERIALS PROPERTIES AND EXPERIMENTAL INVESTIGATION

3.1MATERIALS

Raw materials required for the concreting operations of the prevailing work are silica fume , Copper Slag, cement, fine aggregate, coarse aggregate, and water..

3.2CEMENT

Ordinary Portland cement is the most common type of cement in general use around the world as a basic ingredient of concrete, mortar, stucco, and most non- specialty grout. Cement is the main ingredient in manufacturing of concrete. The characteristics of concrete will be greatly affected by changing the Cement content. The Cement used in this project is Ordinary Portland Cement of 53 grade confirming to IS 12269 – 2013.

S No	Properties	Values observed
1	Specific Gravity	3.15
2	Normal consistency	32%

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3	Initial setting time	33 min
4	Final setting time	480 min
5	Soundness	8.7 mm

3.1 Physical properties of Ordinary Portland cement -53 Grade

3.3FINE AGGREGATE

Gradation refers to the particle size distribution of aggregates. Grading is a very important property of aggregate used for making concrete, in view of its packing of particles, resulting in the reduction of voids. This in turn influences the water demand and cement content of concrete.

Grading is described in terms of the cumulative percentages of weights passing a particular IS sieve. IS 383-1970 specifies four ranges or zones for fine aggregate grading. Table gives the range of percentage passing for each zone.
Zone I sand is the coarsest and Zone IV is the finest whereas sand in Zone II and Zone III are moderate. It is recommended that fine aggregates conforming to grading zone II or Zone III can be used in reinforced concrete.

S.No	Property	Result
1	Fineness Modulus	2.76
2	Specific Gravity	2.75

3.2 Physical properties of fine aggregates

3.4 COARSE AGGREGATE

The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate. The normal maximum size is gradually 10-20 mm; however particle sizes up to 40 mm or more have been used in Self Compacting Concrete. Gap graded aggregates are frequently better than those continuously graded, which might expensive grader internal friction and give reduced flow
Locally available coarse aggregate having the maximum size of 20 mm and minimum size of 12.5 mm was used in this work. The aggregates were washed to remove dust and dirt and were dried to surface dry condition. The aggregates were tested as per IS: 383-1970.

S.No	Property	Result
1	Fineness Modulus	8.3
2	Specific Gravity	2.71

3.3 Physical properties of coarse aggregates

3.4 SILICA FUME

Silica fume, also referred as micro silica or condensed silica flume, is any other fabric this is used as synthetic mineral admixtures
Silica fume as an admixture has opened a new development in concrete era. The utilization of first rate plasticizer with silica fume has been the spine of contemporary excessive overall performance concrete. It should be stated that silica fume by using itself, doesn’t make contributions to electricity. However it produces the assets of energy being great pozzolanic fabric. Silica fume facilitates in discount of water turns into feasible in presence of excessive dosage of superb plasticizer and dense packing of cement paste..

3.5 COPPER SLAG

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.. 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. Due to the same reasons the granulated slag is usable as a filler and insulating material in house foundations in a cold climate. Numerous houses in the same region are built with a slag insulated foundation

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S.No	Property	Result
1	Fineness Modulus	3.4
2	Specific Gravity	4.12
3	Bulk density	2.31 G/CC

Table no 3.7 physical properties of copper slag

4. MIX DESIGN

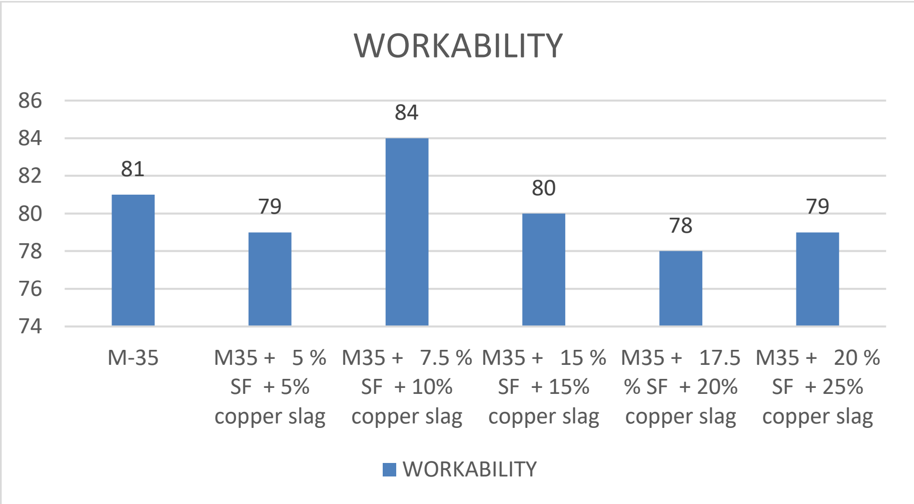
Cement	Fine aggregate	Coarse aggregate	Water
492.0	722.37	1056.87	197.16
1	1.46	2.14	0.40

Table no 4.1 mix proportion for m35 grade

5. RESULTS

5.1 SLUMP CONE TEST

The strength of concrete of a given mix proportion is seriously affected by the degree of its compaction. It is therefore important that the consistency of the mix is such that the concrete can be transported, placed and finished sufficiently easily and without segregation. A concrete satisfying these conditions is said to be workable. Workability is a physical property of the concrete depending on the external and internal friction of the concrete matrix; internal friction being provided by the aggregate size and shape and external friction being provided by the surface



Graph no 5.1 workability results

5.2 COMPACTION FACTOR TEST

Scope and Significance Compaction factor test is adopted to determine the workability of concrete, where nominal size of aggregate does not exceed 40mm, and is primarily used in laboratory. It is based upon the definition, that workability is that property of the concrete which determines the amount of work required to produce full compaction. The test consists essentially of applying a standard amount of work to standard quantity of concrete and measuring the resulting compaction. To find the workability of freshly prepared concrete, the test is carried out as per specification of IS: 1199-1959.

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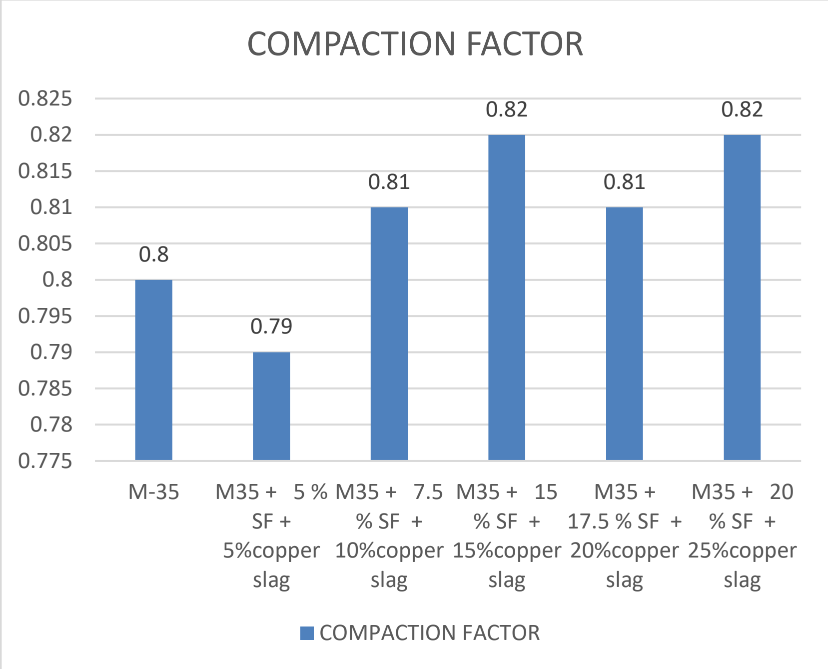
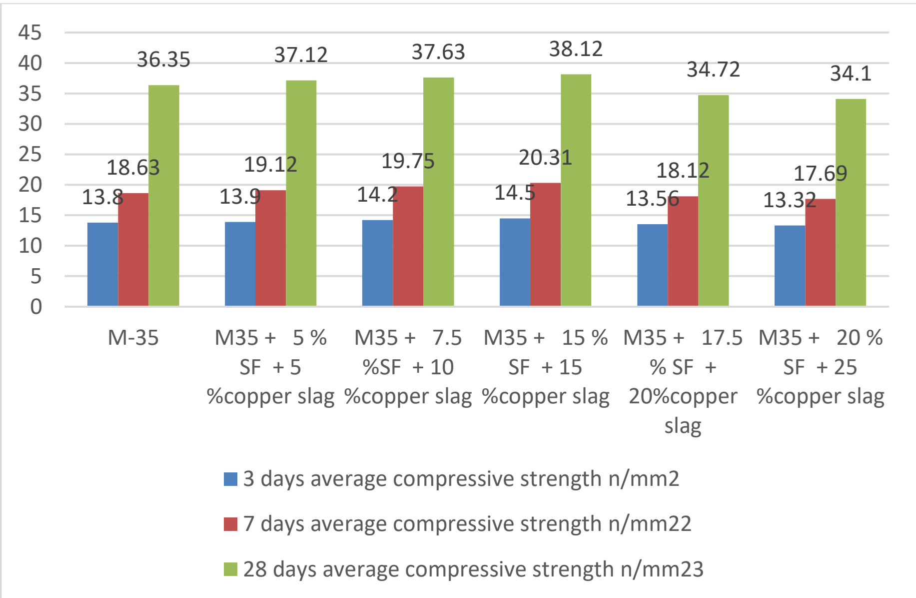


Graph no 5.2 compaction factor results

5.3 COMPRESSION TEST ON CONCRETE CUBES

The determination of the compressive strength of concrete is very important because the compressive strength is the criterion of its quality. Other strength is generally prescribed in terms of compressive strength. The strength is expressed in N/mm2. This method is applicable to the making of preliminary compression tests to ascertain the suitability of the available materials or to determine suitable mix proportions. The concrete to be tested should not have the nominal maximum size of aggregate more than 20mm test specimens are either 15cm cubes or 15cm diameter used. At least three specimens should be made available for testing. Where every cylinder is used for compressive strength results the cube strength can be calculated as under. Minimum cylinder compressive strength = 0.8 x compressive strength cube (10 cm x 10 cm) The concrete specimens are generally tested at ages 3 days 7 days and 28 days. The cubes are generally tested at 3 days 7 days and 28 days.



Graph no 5.3 compressive strength results for 3, 7 and 28 days

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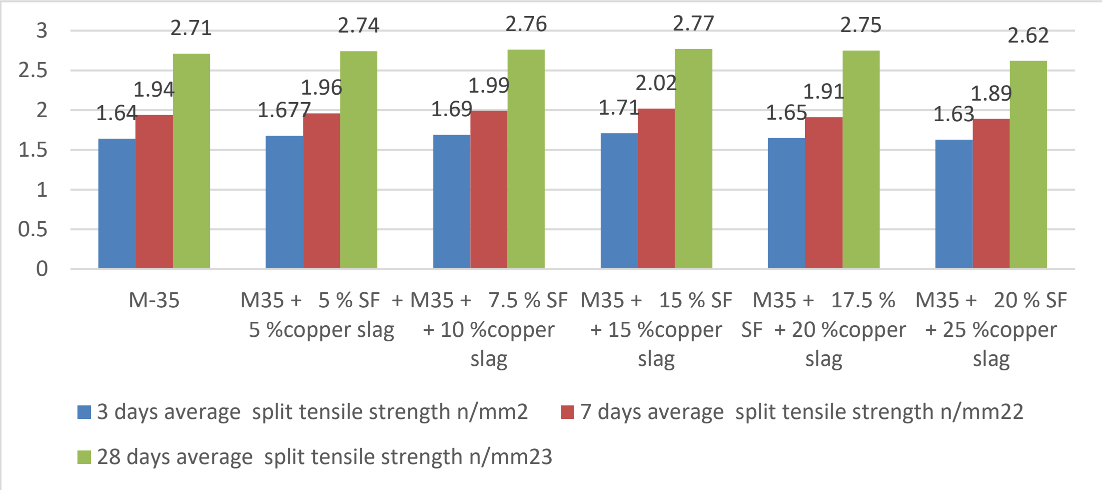
3.4 SPLIT-CYLINDER TEST

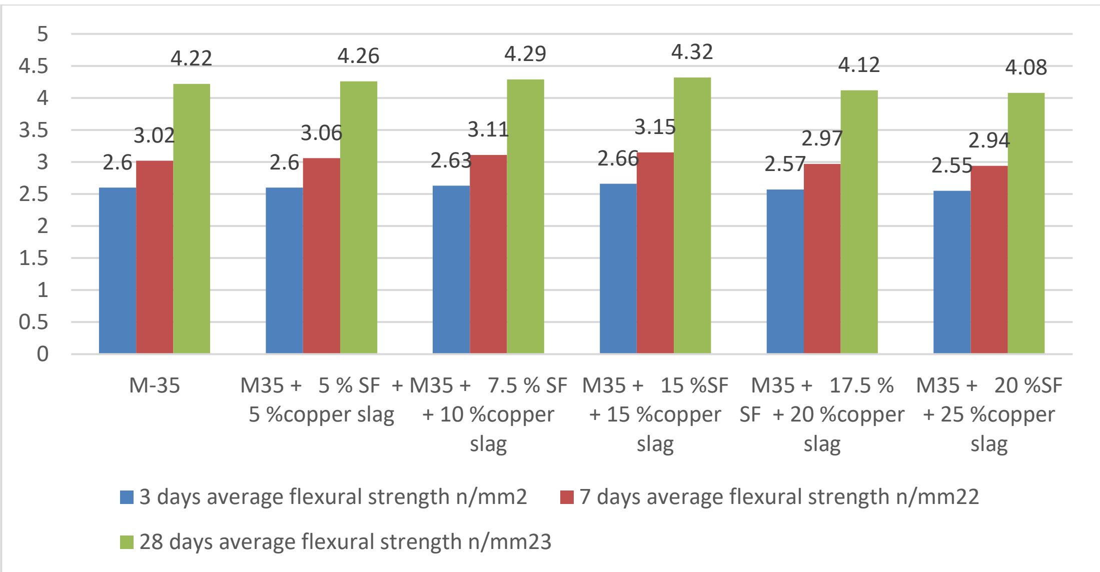
It is the standard test, to determine the tensile strength of concrete in an indirect way. This test could be performed in accordance with IS : 5816-1970.A standard test cylinder of concrete specimen (300 mm X 150mm diameter) is placed horizontally between the loading surfaces of Compression Testing Machine. The compression load is applied diametrically and uniformly along the length of cylinder until the failure of the cylinder along the vertical diameter. To allow the uniform distribution of this applied load and to reduce the magnitude of the high compressive stresses near the points of application of this load, strips of plywood are placed between the specimen and loading platens of the testing machine. Concrete cylinders split into two halves along this vertical plane due to indirect tensile stress generated by poison's effect.



Graph no 5.4 split tensile strength results for 3, 7 and 28 days

5.5 FLEXURAL STRENGTH OF CONCRETE

The flexural strength would be the same as the tensile strength if the material were homogeneous. In fact, most materials have small or large defects in them which act to concentrate the stresses locally, effectively causing a localized weakness. When a material is bent only the extreme fibers are at the largest stress so, if those fibers are free from defects, the flexural strength will be controlled by the strength of those intact 'fibers'. However, if the same material was subjected to only tensile forces then all the fibers in the material are at the same stress and failure will initiate when the weakest fiber reaches its limiting tensile stress. Therefore, it is common for flexural strengths to be higher than tensile strengths for the same material. Conversely, a homogeneous material with defects only on its surfaces (e.g., due to scratches) might have a higher tensile strength than flexural strength.



Graph no 5.5flexural strength results for 3, 7 and 28 days

6. CONCLUSION

- We gain the highest compressive strength at the percentage of different admixtures added in M-35 grade concrete (M35 + 15 % sf + 15% copper slag)– 38.12 N/mm2
- We gain the highest split tensile strength at the percentage of different admixtures added in M-35 grade concrete (M35 + 15 % sf + 15% copper slag)– 2.77 N/mm2
- We gain the highest flexural strength at the percentage of different admixtures added in M-35 grade concrete (M35 + 15 % sf + 15% copper slag) – 4.32 N/mm2

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AUTHOR'S PROFILE

MAHANKALI SRIKANTH pursuing M.Tech in department of CIVIL (STRUCTURAL ENGINEERING)Newton's Institute of Science and technology.

P. BALAKRISHNA Working as Assistant Professor in Newton's Institute of Science and technology.