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USING COPPER SLAG AND FLY ASH FOR SUSTAINABLE CONCRETE PRODUCTION

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ABSTRACT
This paper investigates the wellbeing aspects of concrete incorporating copper slag (CS) as Part fine aggregate and fly-ash (FS) as part cement. CS and FS are the two types of waste Produced by industries. The use of these industrial waste material in concrete is the Motivation of this experimental work. Different grades as per Indian Standards were M20 grade Concrete with the incorporation of CS content and varying up to 60% of CS. In all these mixes,10% FS with cement has been used as a binding material. A definite standard mix for 0% CS & 0% FS is prepared which is used for comparison purposes for all other mixes with respect to The fresh and hardened properties. Cubes and cylinders were fabricated for the mixes and sufficient Curing was done for seven and twenty-eight days respectively. Studies are Required in order to understand the fresh & hardened concrete properties. To determine how Well the concrete can be placed without segregation a slump cone test is performed (Fresh Concrete properties). Compression, split tensile, test is carried out to study split tension in Hardened concrete. The test results have shown that, the degree of benefit, in terms of the particular Strength properties achieved was considerable as compared to normal concrete. The workability Decreased as the CS content was increased and workability was improved. In the mixture that built up their strength with a maximum of CS 40% and FS 10%, the strengths obtained Were the highest. Hence, it is better to incorporate 40% copper.

Keywords: Copper Slag, Fly Ash, Compressive Strength, Split Tensile Strength.

1. Introduction

In India, the increased urbanization along with technological advancements makes it easier to generate industrial by products and waste materials. Among these, it is important to highlight the possibility of employing recycling copper slag, which is a waste in the process of copper smelting and refining, and fly-ash, a waste material generated primarily in coal combustion power plants in the construction sector. Due to its similar characteristics to sand, copper slag can be used to replace fine aggregates in concrete without causing any pollution to the environment as well as reducing the cost of construction. Likewise, coal-based Class F fly ash has also acted as a partial replacement for cement due to its strength and durability in concrete.

These waste materials are classified under the green concept that aims at incorporating green technologies in the construction processes. Green concrete has the advantages of reduction of the consumption of natural resources, reduction of energy consumption, and consumption of waste materials during concrete manufacture. It has been established that concrete made with copper slag and fly ash incorporates strength, durability, and cost efficiency that are superior to that of conventional concrete. The paper discusses the role of copper slag and fly ash as replacement materials in the concrete industry.

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2. Literature review

Chandrasekaran et al. (2021) emphasized the long-term durability performance of copper slag and fly ash concrete under aggressive environmental conditions. Their research showed that concrete containing copper slag exhibited superior resistance to abrasion and thermal cracking, while the fly ash improved the resistance to sulfate and acid attacks. From an environmental perspective, the incorporation of these industrial by-products significantly lowers the carbon footprint of concrete production by reducing reliance on cement and virgin aggregates. However, the environmental assessment of the full lifecycle of such concrete requires further studies to quantify the overall sustainability benefits.

Patil et al. (2022) showed that copper slag can replace up to 50% of fine aggregates without compromising concrete's compressive strength. Its angular shape and granular structure also improve the workability of the concrete mix. However, higher replacement levels might cause an increase in the density and decrease the tensile strength of concrete, which requires further optimization of mix design for specific applications.

Alam et al. (2023) discussed issues related to the variability in the chemical composition of copper slag and the availability of fly ash, especially with the shift to renewable energy sources reducing fly ash production from coal-fired plants. Additionally, there are concerns over the leaching of heavy metals from copper slag, which need to be addressed through proper material testing and mix design optimization. Future research should focus on developing standardized guidelines for the use of these materials, integrating life cycle assessments, and exploring alternative sources for SCMs as part of a sustainable construction strategy.

Singh and Gupta (2023) highlighted its pozzolanic properties, which contribute to the long-term strength gain and resistance to sulfate attack. Fly ash substitution reduces the amount of Portland cement required in the mix, directly contributing to CO_2 emission reductions in concrete production. Additionally, research indicates that fly ash enhances the workability and long-term durability of concrete, especially in high-performance and self-compacting concrete.

3. Objective

1. The aim of this work is to utilize copper slag and fly ash in partial replacement of sand and cement respectively in order to produce concrete of enhanced strength and durability with a focus on sustainable development.
2. This study aims to determine the maximum allowable proportions of copper slag and fly ash that can be effective as partial exchange for fine aggregate and cement.
3. This section reviews the literature on use of copper slag and fly ash in concrete.
4. Meet green concrete constraints by incorporating industrial by product into concrete mix as added binder.

4. Materials and methodology

4.1 Cement:

In this work of investigation, 43 grade Ordinary Portland cement are used. The tests of cement are carried out in the examination of the properties of cement according to IS 12269-1987.

Table 1 Properties of cement

Particular	Value
Specific gravity	3.15
Standard consistency	32%
Fineness %	3%
Initial setting time	36min
Final setting time	460min
7days compressive strength (N/mm^2)	28
28dayscompressive strength (N/mm^2)	45

4.2 Coarse aggregate

Table 2 Properties of coarse aggregate

particulars	value
Specific gravity	2.94
Bulk density	1.59
Void ratio	0.87
Fineness modulus	3.06

4.3 Fine aggregate

Table 3 Properties of fine aggregate

particulars	value
Specific gravity	2.3
Bulk density	1.45
Void ratio	0.64
Fineness modulus	3.06

4.4 Copper slag

Table 4 Properties of copper slag

Particulars	value
Particle shape	Irregular
Appearance	Black and glassy
Fineness modulus	4.39
Water absorption	0.18%
Specific gravity	4

4.5 Fly ash

Table 5 Properties of fly ash

Particulars	value
Specific gravity	1.8-2.4
Colour	Light grey
Particle shape	spherical
Drying shrinkage(%)	0.10

5.Testing and result

5.1 Compressive strength test

Mechanical test measuring the maximum amount of compressive load material can bear before fracturing. Here cube of size is 150*150*150mm casted and cured.

Table 6 Compressive strength test result

Name of the cube sample	Fly ash%	Copper slag%	Compressive strength(N/mm^2)	
			7days	28days
A	0	0	14.55	25.2
B	10	10	15.8	26.01
C	10	20	16.66	26.59
D	10	30	17.45	27.83
E	10	40	19.28	32.60
F	10	50	18.22	24.32

Graphical representation

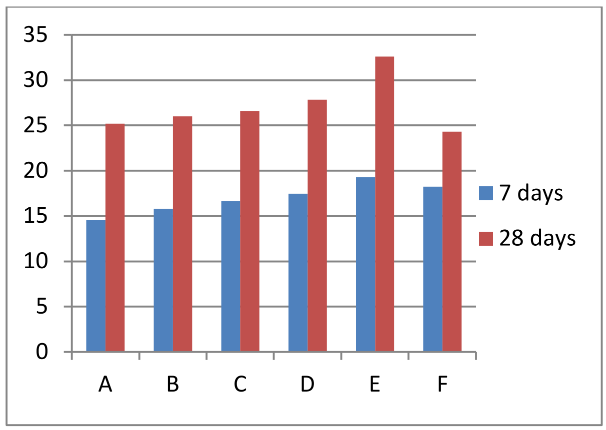

Fig-1 7 days and 28 days compressive strength of concrete

5.2 Discussion

- Strength with Increase in Percentage of Copper Slag It is evident that with the increase in percentages of copper slag, strength also increased. It is found that the replacement of 40% copper slag has gained the maximum compressive strength. At the time of 28 days, it presented about 32.60 Mpa compared to the control mixture that is about 25.50 Mpa.
- In the case of the concrete, compressive strength increases with the percent of copper slag up to 40% beyond this percentage

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compressive strength significant decreases due to the increase free water content in mixes.

- This implies that the strength is increased by nearly 40% than the control mix. However, mixtures with 50% replacement of copper slag have given the lowest compressive strength of 24.32 Mpa.
- 10% fly ash replacement indicates good compressive strength at 28 days. Copper slag can replace up to 40% as fine aggregates.

5.3 Split tensile strength

The tensile strength split was determined by testing cylinders of size 150mm diameter by 300mm height in a compressive testing machine. The split tensile strength of concrete was further calculated based on the following formula:
T=2p/(pieDL)

Table 7 Split tensile strength

Designation	28 days
A	1.7
B	1.79
C	1.96
D	2.64
E	2.99
F	2.42

Graphical representation

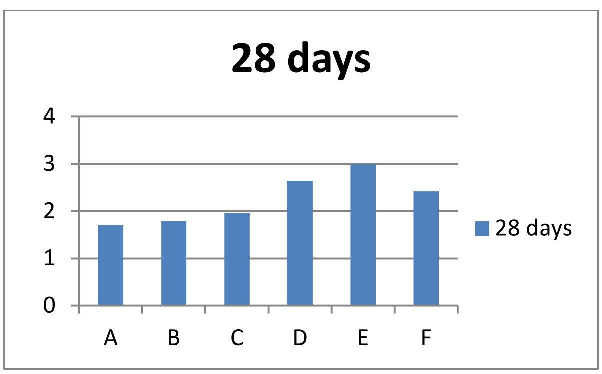

Fig-2 28 days split tensile strength

5.4 Discussion

The highest split tensile strength was achieved with the replacement of 40% of copper slag, which was found to be about 2.99 N/mm2 with respect to 1.8 N/mm2 for the control mix. This simply means an increase in strength by almost 65% compared to the control mix at 28 days. This is because since copper slag has fewer fine particles than fine aggregate, it is accompanied by increased voids, and this reduction could be further due to the increase of free water because the copper slag absorbs less water than the fine aggregate.

6. Conclusion

Results From the above data, it was found that there was a significant increase in strength when we replaced sand with copper slag and cement with fly ash. Using fly ash as a substitute for Portland cement, reduces the overall cost of concrete materials. We are using OPC of 43 grade, class F fly ash, and well graded coarse and fine aggregate.

This slag can replace up to 40% of the amount of copper slag to give maximum workability. When percent replacement of copper slag in concrete was increased beyond 40%, the workability of the concrete decreased. Among the mixes in the other combinations, 40% attained only ultimate compressive strength after later ages. At later ages beyond ultimate compressive strength segregation and bleeding contribute to loss in concrete strength.

E mix achieves maximum split tensile strength due to high toughness of Copper Slag. On the basis of cost, per cent reduction in cement and fine aggregate reduce the cost of concrete but simultaneously increase its strength also. The E mix is economically most beneficial by possessing a high strength than the control mix.

7.References

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