Effect of Copper Slag and Fly Ash on High Strength Concrete

Merla Sarat[1], R.Rama Krishna[2]
[1, 2] Department of Civil Engineering
[1, 2] Kakinada Institute of Technology and Science, Divili

Abstract- *Concrete is an extraordinary building material in the human history. It is no doubt that with the improvement of human civilization, concrete will continue to be a governing construction material in the future. Concrete is one of the necessary elements for structural work in the modern construction. In the decade, buildings around the world have become higher and so the structural strength demand for concrete is increased. Hence, they require high strength concrete.*

In this present work, an experimental investigation was conducted to study the effect of using copper slag as a fine aggregate and the effect fly ash as partial replacement of cement on the properties high strength concrete. Totally ten concrete mixtures were prepared. Five mixes containing different proportions of copper slag ranging from 0% (for the control mix) to 75%.Five mixes containing fly ash as partial replacement of cement ranging from 6% to 30%(all 5 mixes contains 50% copper slag as sand replacements) . Concrete mixes were tested for workability, density, compressive strength, tensile strength, flexural strength and durability. The results indicate that there is a slight increase in the density of nearly 6% with the increase of copper slag content, whereas the workability increased with increase in copper slag percentage. Addition of up to 50% of copper slag as sand replacement yielded comparable strength with that of the control mix. However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix. Mix with 75% copper slag replacement gave the lowest compressive strength value of approximately 80 MPa, which is almost 4% more than the strength of the control mix. For this concrete containing 50% copper slag, fly ash is introduced in the concrete for better performance. Introduction of fly ash gave better results than concrete containing 50% copper slag.The strength has increased approximately 3% containing 18% fly ash and decreased with further replacements of cement with fly ash. Whereas, workability got increased with further increase in fly ash content. Therefore, it is recommended that 50% of copper slag can be used as replacement of sand and 18% fly ash can be used as replacement of cement in order to obtain high strength concrete with better performance with good strength and durability properties.

I. INTRODUCTION

Concrete is a highly important building material in the human history. It is no doubt that with the improvement of human civilization, concrete will continue to be a governing construction material in the future. Concrete is probably the most widely used construction material in the world. It is only second to water as the most profoundly consumed substance with about six billion tons being produced every year. In 2011, about 3.8 billion tons of cement was produced worldwide, which can be translated to about 38 billion tons of cement-based products (from which concrete is the majority), assuming that cement constitutes 10% of their mass. Such a common application of concrete and other cement based materials is caused by a number of factors, including their worldwide availability, relatively low price, good mechanical properties and durability.

Concrete having compressive strengths of 20-40 N/mm2 has been usually used in constructions. With the demand for more advanced structural practices along with deterioration , long term poor performance of conventional concrete led to enhanced explorations for development of concrete which would tally on all the aspects that a new construction material is evaluated upon strength, workability, durability, affordability and will thus facilitate the construction of maintainable and cost-effective buildings with an extraordinary design moreover providing a material that will have long term better performance and reduced maintenance. The development of high performance concrete in this regard has been a great innovation in concrete technology. ACI defines High Performance Concrete as “Concrete having special features of performance and consistency requirements that are not always be achieved regularly using conventional ingredients and normal mixing, placing and curing practices”. Main factors for High Performance Concretes are strength, long term durability, serviceability as determined by crack and deflection control, along with response to long term environmental effects. High performance concretes (HPC) are those concretes which are having properties which satisfy the various performance standards. Generally, concretes with higher strengths and qualities superior to conventional concretes are called High performance concrete. Hence HPC can be considered as a logical improvement of cement concrete in which the constituents are proportioned and nominated to contribute efficiently to the different properties of cement concrete in fresh and also in hardened states.

II. LITERATURE REVIEW

Introduction

This chapter deals with the review of the existing literature on the use of copper slag and mineral additives in concrete. The most important investigations, related to the current investigation, are summarized and salient facts which seem to emerge from the research discussed. The discussion is generally confined to the durability and strength characteristics of concrete with copper slag and mineral admixtures such as silica fume and fly ash.

Fresh concrete properties

Khalifa S. Al-Jabri ,Makoto Hisada et al(2009), This research study was conducted to investigate the performance of high strength concrete (HSC) made with copper slag as a fine aggregate at constant workability.Six concrete mixtures were prepared with different proportions of copper slag at constant workability. The water content was adjusted in each mixture in order to achieve the same workability as that for the control mixture. The results indicated that the water demand reduced by almost 22% at 100% copper slag replacement compared to the control mixture.

Khalifa S.Al-Jabri , Makoto Hisada et al.(2009), had done an experimental program to investigate 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.The results indicate that there is a slight increase in the HPC density of nearly 5% with the increase of copper slag content, whereas the workability increased rapidly with increases in copper slag percentage.

Wei Wu, Weide Zhang , Guowei M (2010) This study investigated the mechanical properties of high strength concrete incorporating copper slag as a fine aggregate and concluded that the workability even had a dramatic growth with increase in copper slag percentage.

III. MATERIAL PROPERTIES & EXPERIMENTAL PROGRAMME

General

To achieve the objectives of the study, an extensive experimental programme was planned which included evaluation of slump, compressive strength, split tensile strength, flexural strength properties at various ages of concrete containing copper slag as sand replacement, fly ash as partial substitution of cement. This chapter outlines the experimental programme planned for this study in detail. The properties of the concrete making materials, concrete mix details, casting, curing, workability of concrete, details of tests performed on hardened concrete are presented.

Test Programme

The following test programme was planned to explore the fresh and strength properties of concrete:

- To obtain the physical properties of the concrete constituents i.e. ordinary Portland cement (OPC), sand, coarse aggregate and mineral admixtures used are as per relevant ACI and IS Codes of Practice.
- Obtaining the design mix for concrete.
- Testing the workability of concrete
- Casting and curing of specimens.
- Testing of specimens for compressive strength, split tensile strength and flexural strength.
- Determining the effects of substitution of copper slag as fine aggregate and fly ash as partial replacement of cement with various percentages on fresh, hardened properties.

Physical properties of cement

Sieve size (mm)	Retained weight (g)	% weight Retained	Cumulative % Retained (F)	Cumulative % Passing (100-F)
20	0	0	0	100
16	0	0	0	100
12.5	20	1	1	99
10	236	11.8	12.8	87.2
4.75	1456	72.8	85.6	14.4
2.36	269	13.45	99.05	0.95

Particulars	Test result	Requirement as per IS:12269-1987
Chemical Composition		
% Silica(SiO_2)	**19.79**	
% Alumina(Al_2O_3)	**5.67**	
% Iron Oxide(Fe_2O_3)	**4.68**	
% Lime(CaO)	**61.81**	
% Magnesia(MgO)	**0.84**	Not more Than 6.0%
% Sulphuric Anhydride (SO_3)	**2.48**	Max. 3.0% when $C_3A>5.0$ Max. 2.5% when $C_3A<5.0$
% Chloride content	**0.003**	Max. 0.1%
Lime Saturation Factor CaO-$0.7SO_3/2.8SiO_2+1.2Al_2O_3+0.65Fe_2O_3$	**0.92**	0.80 to 1.02
Ratio of Alumina/Iron Oxide	**1.21**	Min. 0.66

Coarse aggregates

The material which is retained on 4.75 mm sieve is known as coarse aggregate. Locally available 10 mm coarse aggregates were used in this work conforming to IS: 383-1970, with properties as given in table 2.73, respectively. Sieve analysis of 10mm size coarse aggregates is as shown in table 3.5

Weight of sample taken = 2000 grams
Fineness modulus of coarse aggregates = 5.98
Physical properties of 10mm coarse aggregates.

Table 3.5 Sieve analysis of 10mm coarse aggregates

Physical tests	Values
Specific gravity	2.72
Fineness modulus	5.98
Water Absorption (%)	0.3
Bulk density (compacted) (kg/m^3)	1453
Bulk density (loose) (kg/m^3)	1649

Fly ash

Fly ash as shown in fig was obtained from "NTPC"thermal power plant. The physical properties of fly ash are as shown in table

Physical properties of Fly ash

S.NO	Physical Properties	Test Results
1	Colour	Grey
2	Specific gravity	2.2

Silica fume

Physical properties of silica fume

The primary properties of silica fume are discussed below

Particle size

Silica fume has the very small size particles, with more than 95 percent of the particles being less than one micrometer (1 µm). Particle size is extremely important for both physical and chemical contribution.

Bulk density

This simply shows the term for unit weight. The bulk density of the silica fume relies on the metal being made in the kind of heater and upon how the heater is worked due to the created silica fume is normally low it is not prudent to transport it for more distances.

Specific gravity

Specific gravity that tells how silica fume contrasts with water, which has a specific gravity of 1.0. This number is used in proportioning concrete silica fume has specific gravity of about 2.2 to 2.7, which is having somewhat less weight than Portland cement, which has specific gravity of 3.15. Thus adding silica fume to concrete mixture would have not "densify" the concrete in terms of increasing the density of concrete.

Specific surface

Specific surface area defined as the total area of given mass of concrete. Due to the silica fume particles are little, the surface area is higher. We well realize that water request increments for sand as the particles size get to be exceptionally more diminutive. The same thing is happen for silica fume. This is the reason it is important to utilize silica fume in mix with the water reducing admixture or super plasticizer. Brunauer Emmittt Teller (BET) and Nitrogen absorption methods are specialized methods which must be utilized to measure the specific surface of the silica fume..

Silica as shown in fig 3.5 was obtained from 'astraa chemicals'. The physical properties of silica fume are as shown in table 3.8.

Table 3.8 Physical properties of silica fume

S.NO	Physical Properties	Test Results
1	Colour	white
2	Specific gravity	2.63

Super plasticizer

A new generation of super plasticizers, based on polycarboxylate ether polymers allows the reduction of water content of up to 40%.

In order to increase the strength and also reduce the porosity (impermeability),i.e. to extend the durability and thus the life time of a concrete structure it is of utmost importance to keep the w/c as low as possible. Good mix design with a low w/c ratio must go in line with appropriate placing on the job site.

Master Glenium SKY 8233 is an admixture of another era focused around adjusted poly-carboxylic ether. The product has been primarily developed where the highest durability and performance required, which is free of chloride and low alkali content. It is perfect with different varieties of cements

A severe over-dosage of Master Glenium SKY 8233 can result in the following:

1. Extension of initial and final set
2. Bleed/segregation of mix, quick loss of Workability
3. Increased plastic shrinkage

A slight overdosing may not adversely affect the ultimate strength of the concrete and can achieve higher strengths than normal concrete, provided it is properly compacted and cured

Master Glenium sky 8233 (BASF Company) as shown in fig 3.6 is used as high range water reducer (HRWR) SP. The properties of the chemical admixtures as obtained from the manufacturer are presented in the Table

IV. RESULTS AND DISCUSSION

General

In this chapter, experimental investigations were carried out to study the influence of the copper slag and fly ash admixtures on the fresh properties (Slump), hardened properties (Compressive strength, Tensile strength, flexural strength) of concrete.

Therefore, an investigation program was carried out with 10 different concrete mixes having different fine aggregate and cement replacement levels. The detailed analysis and discussion of test results as obtained from the test program are presented in the following sections.

Fresh properties of Concrete

Workability and density

The effect of copper slag replacement as fine aggregates on the workability and density of high strength concrete is presented in Table for different proportions of copper slag. The workability of concrete was considered based on the measured slump of fresh concrete. It is clear that the workability of concrete increases with the increase of copper slag content in concrete mixes. For the control mixture (i.e. Mix 1), the measured slump was 48 mm whereas for Mix 5, with 75% replacement of copper slag, the measured slump was 82mm. This increase in the workability with the increase of copper slag quantity is due to the low water absorption characteristics of copper slag and its glassy surface. However, it should be noted that mixes with high contents of copper slag (i.e. M4) showed signs of bleeding and segregation which can have disadvantageous effects on concrete performance. Also Table shows that there is general slight increase in the density of high strength concrete with the increase of copper slag quantity. The density of concrete was increased by almost 6%. This is mainly due to the higher specific gravity of copper slag which was 3.51 compared with sand which has a specific gravity of 2.65. And with the replacement of cement with fly ash also tends to increase in workability with a negligible increment in the density. Variation of slump is shown in the fig

Fresh properties of different Concrete mixes

Mix no.	Description	Slump (mm)	Density (kg/m3)
M0	Control (100% S)	48	2460
M1	90% S + 10% C.S	55	2470
M2	75% S + 25% C.S	66	2520
M3	50% S + 50% C.S	74	2550
M4	25% S + 75% C.S	82	2591
M5	50% S + 50% C.S+ 6% F.A	78	2525
M6	50% S + 50% C.S+ 12% F.A	86	2526
M7	50% S + 50% C.S+ 18% F.A	93	2526
M8	50% S + 50% C.S+ 24% F.A	97	2528
M9	50% S + 50% C.S+ 30% F.A	102	2526

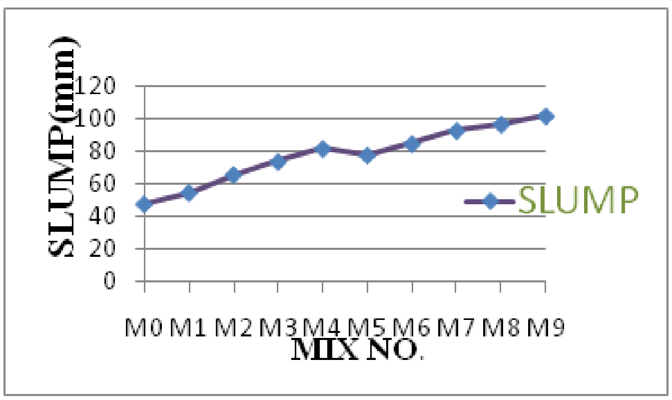


Fig variation of slump value with mixes

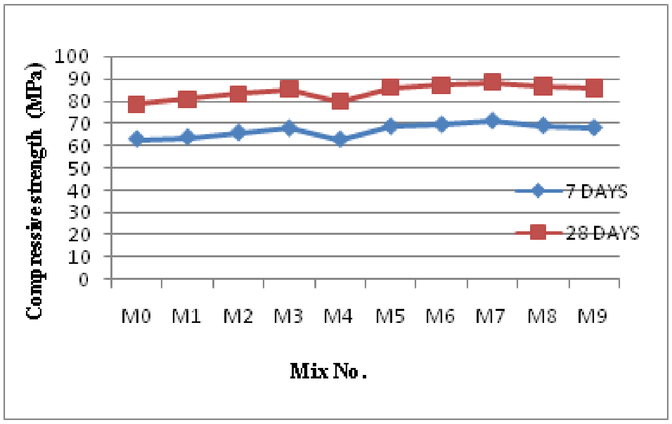
Hardened properties

Strength properties

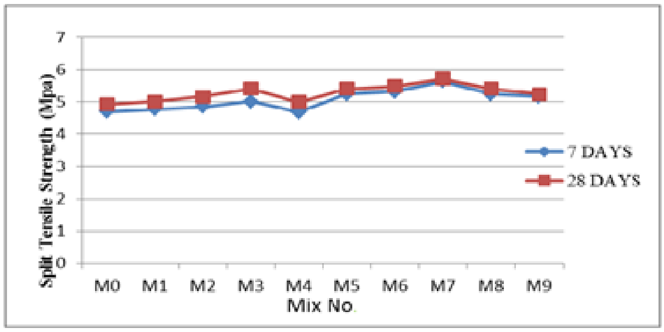
The results of the compressive strength tests conducted on concrete specimens of different mixes water cured at 7days and 28days are presented and discussed in this section. Addition of up to 50% of copper slag as sand replacement yielded comparable strength with that of the control mix. However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix. Whereas, replacement of cement with fly ash caused increment in strength up to 18% (including 50% copper slag). Mixtures (M4) with 75% copper slag replacement gave the less compressive strength value which was almost 7% lower than the strength of the HSC with 50% copper slag replacement. Mixtures with 24% and 30% fly ash (including 50% copper slag) gave lowest compressive strength value which was almost 2% lower than the strength of HSC without replacement of fly ash. It is recommended that 50 % of copper slag can be used as replacement of sand and 18% fly ash can be used as replacement of cement in order to obtain HPC with good properties. Split tensile strength and flexural strengths of the mixes also follows the same pattern as compressive strength. Optimum mix M7 has maximum split tensile strength and maximum flexural strength.

Strength results of all mixes in water curing of 7-days and 28-days

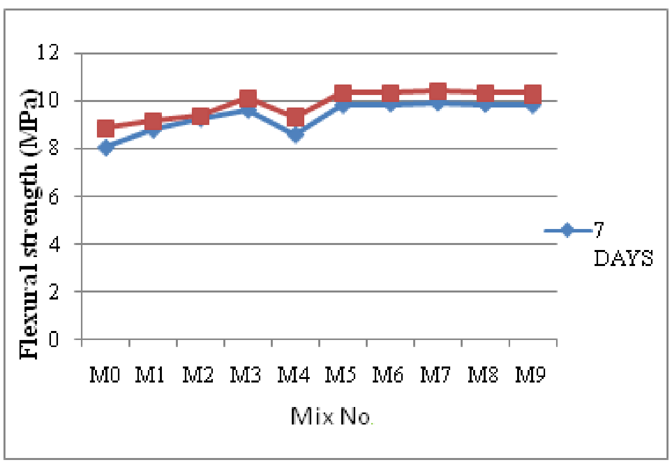
Mix No	Mix Propotions	Compressive Strength (MPa)		Tensile Strength (MPa)		Flexural Strength (MPa)	
		7 Days	28 Days	7 Days	28 Days	7 Days	28 Days
M0	Control (100% S)	62.83	78.66	4.695	4.93	8.04	8.87
M1	90% S + 10% C.S	63.66	80.83	4.77	5.013	8.79	9.17
M2	75% S + 25% C.S	65.66	83.3	4.85	5.17	9.25	9.41
M3	50% S + 50% C.S	67.66	85.33	5.013	5.41	9.61	10.12
M4	25% S + 75% C.S	62.66	79.83	4.69	5.01	8.58	9.34
M5	50% S + 50% C.S+ 6% F.A	68.5	86.0	5.25	5.41	9.82	10.36
M6	50% S + 50% C.S+ 12% F.A	69.3	87.16	5.33	5.49	9.88	10.38
M7	50% S + 50% C.S+ 18% F.A	71.0	88.33	5.65	5.72	9.92	10.42
M8	50% S + 50% C.S+ 24% F.A	68.83	86.66	5.25	5.41	9.86	10.36
M9	50% S + 50% C.S+ 30% F.A	67.83	85.83	5.17	5.25	9.82	10.32



Variation of compressive strength with mixes



Variation of split tensile strength with mixes



Variation of flexural strength with mixes

V. CONCLUSIONS

CONCLUSIONS

From this study, it was concluded that copper slag as fine aggregate and fly ash as cement replacement material are advantageous in terms of fresh property parameters, mechanical properties. The following conclusions can be drawn based on the results of this work,

- The degree of workability improved with the addition of copper slag. This increase in the workability with the increase of copper slag quantity is due to the low water absorption characteristics of copper slag and its glassy surface. With the replacement of cement with fly ash also tends to increase in workability with a negligible variation in the density.
- Compared to the control mix, there was a slight increase in the high strength concrete density of nearly 6% with the increase of copper slag content
- Addition of up to 50% of copper slag as sand replacement yielded comparable strength with that of the control mix. However, further additions of copper slag caused reduction in the strength due to an increase of the free water content in the mix. Whereas, replacement of cement with fly ash caused increment in strength up to 18% (including 50% copper slag).
- Mixtures with 75% copper slag replacement gave the less compressive strength value which was almost 7% lower than the strength of the high strength concrete with 50% copper slag replacement.
- Mixtures with 24% and 30% fly ash (including 50% copper slag) gave lowest compressive strength value which was almost 2% lower than the strength of high strength concrete without replacement of fly ash.
- It is recommended that 50 % of copper slag can be used as replacement of sand and 18% fly ash can be used as replacement of cement in order to obtain high strength concrete with good properties.

SCOPE FOR FUTURE STUDY

The following proposals are made for future study

- ➢ The present study can be extended to investigate other properties such as depth of penetration, ultra sonic pulse velocity, water absorption etc, with varying percentages of copper slag and fly ash.
- ➢ Durability aspects such as, Sulphate resistance, Alkali resistance, RCPT (Rapid Chloride Penetration Test), can also be investigated.
- ➢ The superplasticizer content was kept constant in the present study; by varying the superplasticizer content, effect of water/powder ratio and compressive strength can be compared.
- ➢ The study can be further extended by incorporating other filler materials like Metakaolin, Blast furnace slag, Rice Husk Ash etc, and studying fresh, hardened, durability properties of concrete using these supplementary materials.

REFERENCES

[1] ACI 211.4R-93(Reapproved 1998), Guide for Selecting Proportions for High-Strength Concrete with Portland Cement and Fly Ash

[2] Afaf Ghais, Duaa Ahmed, Ethar Siddig, Isra Elsadig, Samah Albager, “Performance of Concrete with Fly Ash” International Journal of Geosciences, 2014, 5, 1445-1450.

[3] IS: 12269-1987 “Specifications for 53-Grade Portland cement”, Bureau of Indian Standards, New Delhi, India.

[4] IS 516:1959. Methods of tests for strength of concrete, New Delhi, India: Bureau of Indian Standard.

[5] Indian Standard code IS: 383-1970., “Specifications for coarse and fine aggregates from natural source of concrete”, Bureau of Indian standards, New Delhi, India.

[6] Khalifa S. Al-Jabri , Makoto Hisada b, Abdullah H. Al-Saidy , S.K. Al-Oraimi, “Performance of high strength concrete made with copper slag as a fine aggregate”, elsevier, Construction and Building Materials 23 (2009) 2132–2140.

[7] Khalifa S. Al-Jabri , Makoto Hisada , Salem K. Al-Oraimi , Abdullah H. Al-Saidy, “Copper slag as sand replacement for high performance concrete”, Elsevier, Cement & Concrete Composites 31 (2009) 483–488