Experimental Study on Partial Replacement of Cement and Fine Aggregate by Silicafume and Copper Slag in Concrete

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Abstract- **This paper reports on optimization of partial replacement of cement and fine aggregate by silica fume and copper slag in concrete. Copper slag is one of the materials that are considered as an industrial waste which can be used in construction Industry. About 2.2 tons of copper slag is generated, for every ton of copper production. This paper presents the results of an experimental investigation on the properties of concrete using silica fume and copper slag as partial replacement for cement and fine aggregate. In this research work, M20 grade concrete was used and tests were conducted. Concrete mixtures were evaluated for workability, compressive strength and split tensile strength. The results for concrete indicated that workability increased significantly as silica fume and copper slag percentage increase compared with the control mixture. To determine the compressive strength and tensile strength, cubes and cylinders are casted and its strength is checked at 14 and 28 days. Cement and sand is partially replaced by silica fume and copper slag and compared with the control specimen. Graphical analysis is done for the compressive strength and split tensile strength for the control specimen and silica fume and copper slag replaced concrete.**

I. INTRODUCTION

Protecting the depleting natural sand resource and the shore line is a major concern of the day. It is essential today, to reduce excessive consumption of the natural river sand and there by prevent sand mining. It is possible by utilization of industrial by-products as well as other waste materials in the production of normal concrete. These products can be used as partial and/or full replacement of cement or/and aggregates or as admixtures. Also, many times, it was found that concrete made with wastes and industrial by-products possesses superior properties than the conventional concrete in terms of strength, performance and durability. Hence, in this project, silica fume and copper slag is explored to find its suitability as a replacement material for cement and fine aggregate in making concrete.

Large quantities of waste materials are being generated by various industries and disposal of waste materials is causing environmental and health hazards. For many years, Industrial by-products such as fly ash, silica fume and slag were considered as waste materials. Application of these materials as replacement for cement and sand in Concrete showed improvement in workability and durability compared to normal concrete and has found their application in the many structures. In the recent past, intensive research studies have been carried out to explore all possible recycling and reuse methods. Construction waste, blast furnace Slag, steel slag, coal fly ash and bottom ash have been accepted in many places as alternative aggregates in embankment, roads and pavements.

II. PROBLEM STATEMENT

A large number of wastes materials generated by industries are disposed in the environment. If the wastes cannot be disposed properly it will lead to social and environmental problems. The use of silica fume and copper slag in the concrete as a replacement for cement and fine aggregate, reduces the costs of disposal, lowers the cost of the concrete and also helps in protecting the environment. Despite the fact that several studies have been reported on the effect of silica fume and copper slag on the properties of Concrete, further investigations are necessary in order to obtain a comprehensive understanding that would provide an engineering base to allow the use of silica fume and copper slag in concrete.

III. NEED FOR THE STUDY

Normal concrete lacks required strength, workability and durability which are more often required for large concrete structures such as high rise buildings, bridges, and structures under severe exposure conditions. By increasing concrete strength, the required thickness of concrete members and the cost of concrete structures can both be reduced. Therefore, it is felt necessary to improve the strength and performance of concrete with suitable admixtures to cater present need. In this study, it is planned to replace some percentage of fine aggregate with copper slag. Copper slag admixed long columns was found to provide better ductility and be more effective regarding load carrying capacity compared to control columns.

IV. MATERIALS USED

A. CEMENT

Cement is a binder, a substance that sets and hardens and can bind other materials together.

OPC 53 grade is a higher strength cement to meet the needs of the consumer for higher strength concrete As per BIS requirements the minimum 28 days compressive strength of 53 Grade OPC should not be less than 53 Mpa. For certain specialised works, such as prestressed concrete and certain items of precast concrete requiring consistently high strength concrete, the use of 53 grades OPC is found very useful. The physical properties of Ordinary Portland Cement are shown in the table.

S.No	Description	Physical Properties
1	Fineness	10%
2	Initial Setting time	30 minutes
3	Final Setting Time	12 hours
4	Compressive Strength for 7 days	13.5 N/mm2
5	Compressive Strength for 28 days	20 N/mm2
6	Specific gravity	3.15

B. FINE AGGREGATE

Fine aggregate consists of natural sand, crushed stone sand or crushed gravel stone dust. It should be passed through I. S. Sieve 4.75 mm. It should have the finest modulus 2.50 to 3.50 and silt contents should not be more than 4%. River sand is always used in concrete and building construction work. Sea sand shall not be used in construction work.

C. COARSE AGGREGATE

Coarse aggregate shall be of hard broken stone of granite shall be of hard stone, free from dust, dirt and other foreign matters. The stone ballast shall be of 20mm and down and should me retained in 5mm square mesh and well graded such that the voids do not exceed 42 percent. Aggregate most of which is retained on 4.75-mmIS Sieve and containing only so much finer material as is permitted for the various types described in this standard.

D. SILICA FUME

Silica fume is the byproduct of producing silicon metal or ferrosilicon alloys. One of the most beneficial uses of silica fume uses for concrete because of its physical and chemical properties. Concrete containing silica fume can have high strength and can be durable.

The Physical properties of silica fume is listed in table.

Sl.No	Description	Physical Properties
1	Specific Gravity	2.2
2	Mean Grain Size (Mm)	0.1
3	Colour	Light To Dark Grey

E. COPPER SLAG

Copper slag is a by-product created during the copper smelting and refining process. As refineries draw metal out of copper ore, they produce a large volume of non-metallic dust, soot, and rock. Collectively, these materials make up slag, which can be used for a surprising number of applications in the building and industrial fields.

This material represents a popular alternative to sand as a blasting medium in industrial cleaning. Using blasting or high-pressure spraying techniques, companies can use copper slag to clean large smelting furnaces or equipment. Slag blasting is also used to remove rust, paint, and other materials from the surface of metal or stone. This helps to prep the surface for painting, or simply to remove unwanted finishes or residue. The physical properties of copper slag.

Sl.No	Description	Physical Properties
1	Specific Gravity	3.63
2	Chloride Content	<0.0002
3	Colour	Black colour

F. WATER

Water is a key ingredient in the manufacture of concrete. Attention should be given to the quality of water used in concrete. It plays an important role in the mixing. Good quality water is used. Water which is suitable for drinking is used for concrete.

V. TEST ON MATERIALS

A. TEST ON CEMENT

INITIAL AND FINAL SETTING TIME

SPECIFIC GRAVITY OF CEMENT

The specific gravity is normally defined as the ratio between the weight of a given volume of material and weight of an equal volume of water. To determine the specific gravity of cement, kerosene which does not recent with cement is used. We have taken the specific gravity of cement as 3.15 with the references of literature review.

B. TESTS ON FINE AGGREGATE

SIEVE ANALYSIS

I.S. Sieve Size(mm)	Weight retained (g)	Percentage of weight retained %	Cumulative Percentage of weight retained %	Percentage of Fineness %
4.75	10	0.5	0.5	99.5
2.36	60	3	3.5	96.5
1.18	350	17.5	21	79
600 µ	450	22.5	43.5	56.5
300 µ	920	46	89.5	10.5
150 µ	210	10.5	100	1
Total	2000	100	258	

Fineness modulus of Fine aggregate= ∑ F/100

= 258 /100 = 2.58 (Zone II)

SPECIFIC GRAVITY FOR SAND:

DESCRIPTION	TRIALS		AVERAGE
	1	2	
1)Weight of empty pycnometer (W1)	0.668	0.669	2.5
2) weight of pycnometer + and(W2)	0.868	0.869	
3)Weight of pycnometer +Sand+ water (W3)	1.650	1.652	
4) weight of pycnometer + water (W4)	1.530	1.530	
5)specific gravity	2.5	2.51	

C. TEST ON COARSE AGGREGATE

AGGREGATE IMPACT TEST

Aggregate impact value = (B/A)*100

Where B- Weight of fraction passing 2.36 mm I.S. sieve

A- Weight of oven-dried sample.

From experiment,A = 600g B = 59g

Aggregate impact value = (59/600) x100 = 9.83%

SIEVE ANALYSIS

Locally available 20mm gravel was used as coarse aggregate in the cement concrete mix. The sieve analysis results for coarse aggregate is shown in table

I.S. Sieve size(mm)	Weight retained (g)	Percentage of weight retained %	Cumulative Percentage of weight retained %	Percentage of Fineness %
20	1920	46.26	46.26	53.74
10	2230	53.74	100	0
4.75	0	0	100	0
2.36	0	0	100	0
1.18	0	0	100	0
0.6	0	0	100	0
0.3	0	0	100	0
0.15	0	0	100	0
Total	4150	100	746.26	

Fineness modulus of Fine aggregate= ∑ F/100

= 7.462

SPECIFIC GRAVITY

Locally available 20mm gravel was used as coarse aggregate in the cement concrete mix. The specific gravity results for coarse aggregate is shown in Table,

DESCRIPTION	TRIAL		AVERAGE
	1	2	
1)Weight Of Emptypycnometer (W1)	0.644	0.645	2.86
2) weight of pycnometer +dry aggregate (W2)	0.844	0.845	
3) Weight of pycnometer +Dry aggregate (W3)+ water	1.653	1.655	
4) Weight of pycnometer + water (W4)	1.525	1.525	
5)specific gravity = (W2-W1)/ [(W2-W1)- (W3-W4)]	2.86	2.86	

VI. MIX CALCULATION

MATERIALS REQUIRED FOR 1 m^3 CONCRETE

Cement = 383 Kg/m^3

Fine aggregate = 686 Kg/m^3

Coarse aggregate = 1178 Kg/m^3
Water = $191.6 lit/m^3$
Water cement ratio = 0.50

VII. TEST ON HARDENED CONCRETE

REPLACEMENT DETAILS

The replacement details of silica fume and copper slag has been given in the below table. The replacement of cement by 10% silica fume as constant and varying the fine aggregate replacement percentages by 15%, 30% and 45%. There will be no changes in the quantity of coarse aggregate.

SPECIMEN	CEMENT	SILICA FUME	SAND	COPPER SLAG	COARSE AGGREGATE
K_0	100	-	100	-	100
K_1	90	10	85	15	100
K_2	90	10	70	30	100
K_3	90	10	55	45	100

K_0 refers to, there is no replacement in the concrete mix ratio. K_1 refers to, replacement done in cement by 10% silica fume and fine aggregate by 15% copper slag and no changes in coarse aggregate in the concrete mix ratio. K_2 refers to, replacement done in cement by 10% silica fume and fine aggregate by 30% copper slag and no changes in coarse aggregate in the concrete mix ratio. K_3 refers to, replacement done in cement by 10% silica fume and fine aggregate by 45% copper slag and no changes in coarse aggregate in the concrete mix ratio.

1. COMPRESSIVE STRENGTH

Twenty four cubes are prepared of size 150 mm x 150 mm x 150 mm are checked for compressive strength. The specimen K0, K1, K2 and K3 are tested for 14 and 28 days. The specimen were tested for compressive strength parallel to the plane of the board by applying increasing compressive load until failure occur.

The arrangement of load is applied to the specimen by placing the specimen length vertical between the surfaces of the testing machine. Prior to that, measurement for the thickness and width was carried out in order to get the values of cross section area for the test specimens.

The calculation for compressive strength is obtained from the following equation:

$$Kp = \frac{W}{A}$$

Where, Kp= compressive strength (in N/mm2)
W = the maximum load applied to the test specimen (in N)
A = the cross section of the test specimen (mm2).

2. SPLITTING TENSILE STRENGTH

Twenty four cylinders are prepared of size 150 mm diameter and length 300 mm are checked for splitting tensile test. The specimen K_0, K_1, K_2 and K_3 are tested for 14 and 28 days. The specimens are tested for splitting tensile strength perpendicular to the plane of the board by applying increasing load until failure occurs. The calculation for splitting tensile strength is obtained from the following equation:

$$f_t = \frac{2P}{\pi DL}$$

Where f_t = Tensile strength (in N/mm^2)
P = Load at failure (in N)
D = Diameter of the specimen (in mm)
L = length of the specimen (in mm)

VIII. RESULTS AND DISCUSSION

INTRODUCTION

The present study aims to investigate the compressive strength and basic properties such as moisture content and water absorption of composite made of cement, silica fume, fine aggregate, copper slag and coarse aggregate. Specimen are prepared in certain sizes and cured for 28 days and tested at 14 and 28 days

The amount of cement and fine aggregate are partially replaced by silica fume and copper slag. The silica fume and copper slag is replaced based on the percentage of cement and fine aggregate content. The investigation is expected to have basic characteristics or basic properties of composite materials such as load carrying capacity and durability can be established. Also, the information may be very useful for future study and future development. So improvement to building materials can be carried out in more detail manner.

TESTING PROGRAM

In order to study the behaviour of the replacement specimen concrete with normal concrete. Testing was done to determine the material and structural properties of each type of replacement specimen and will these properties differ according to a different type of mixture and its composition.

Once concrete has hardened it can be subjected to a wide range of tests to prove its ability to perform as planned or to discover its characteristics. For new concrete this usually involves casting specimens from fresh concrete and testing them for various properties as the concrete matures.

The graphical representation shows that the compressive strength for 14 days and 28 days curing strength .

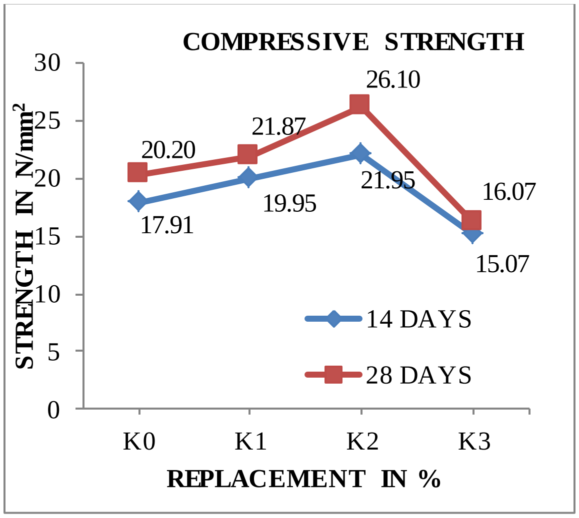

Figure 1: Compressive strength for 14 and 28 days.

The graphical representation shows that the tensile strength for 14 days and 28 days curing strength in fig .,

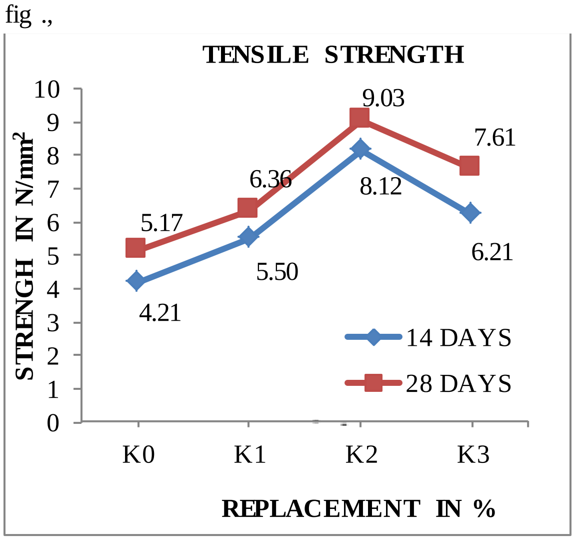

Figure 2: Tensile strength for 14 and 28 days

DISCUSSION

The graph shows the variation of compressive strength of concrete cubes and tensile strength of concrete cubes and cylinders for 14 and 28 curing days from the date of cast of specimen. From this the compressive strength and tensile strength increased gradually up to replacement of cement by 10 % silica fume and fine aggregate by 30 % copper slag.

SUMMARY

Experimental investigations have been carried out on the concrete test specimens to ascertain the strength related properties is compressive strength and tensile strength. Based on the test of 14 days and 28 days of curing results, from obtain result it is very clear that by increasing the replacement percentage of cement by 10 % silica fume and replacement percentage of copper slag up to 30% for fine aggregate has increased about 20 % compressive strength and 15 % tensile strength.

CONCLUSION

We have concluded that workability increases when replacing cement by 10% silica fume. Self weight of the concrete increases while sand is replaced by copper slag due to the density of copper slag. Compressive strength increased by 20% and Tensile strength increased by 15 % by replacing the cement by 10 % silica fume and fine aggregate by 30 % copper slag when comparing to control specimen.

The development in construction technology and architecture has tempted the people to purchase multiple choice materials. Project work gives freedom and opportunity to students to select their own field. This makes, students like us more hopeful it also grows up the operation and understanding between students, which is essential for teamwork.

It also grows up many ideas on selection of project, and also this chance to brush up our activities etc. which are not in syllabus for this semester. On the whole, our project work gives us more hope to march towards a better tomorrow. The project work develops co-operation, co-ordination and awareness of our own individual skills.

IX. REFERENCES

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