Design of Pavement Surface for Sustainable Development Using Micro Silica and Copper Slag

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***Abstract*—— Cement concrete has established its own position among the modern construction materials. Concrete is a basic material used in almost every type of construction, consisting of aggregates that are bond by cement and water. At present, carbon emission and sand mining are major concern due to its hazardous effect to environment and making serious imbalance to the ecosystem. In the construction industry, cement is the main material for the concrete production. The production of cement involves the emission of carbon dioxide during its production. Various studies have been conducted in this regard to reduce severe effect on environment, using industrial by-products like micro silica as partial replacement for cement and copper slag as partial replacement of fine aggregate. The main focus of this experimental program is to investigate the effects of using micro silica partially replacing cement by 0%(control mix), 3%, 6%, 9%, 12% and copper slag partially replacing fine aggregate by 0% (control mix), 20%, 40%, 60% for M50 grade of concrete to know its strength properties without any mineral or chemical admixtures.**

***Index Terms*— concrete, micro silica, copper slag, cement, fine aggregate, strength.**

I. INTRODUCTION

It was observed and noted that since decade of years that the cost of building materials is currently so high that only corporate organization, individual, and government can afford to do meaningful construction. Waste can be used as filler material in concrete admixtures in cement and raw material in cement clinker, or as aggregates in concrete. Concrete is a blend of cement, sand, coarse aggregate and water. Cement concrete most widely used construction material all over the world. It is a material, which is used more than any other man made material on the earth for construction works. In concrete, cement chemically reacts with water and produces binding gel that binds other component together and creates stone type of material. The reaction process is called 'hydration' in which water is absorbed by the cement. In this process apart from the binding gel, some amount of lime [$Ca(OH)_2$] is also liberated. The coarse and fine aggregates act as filler in the mass.

In the present scenario, environmental pollution is the biggest menace to the human race on this planet causing ecological imbalance. There are many reasons which cause pollution. In the construction industry, cement is the main ingredient for the concrete production. The production of cement involves the emission of carbon dioxide during its production. There are two different sources of carbon dioxide emission during cement production. Combustion of fossil fuels to operate the rotary kiln is the largest source and other one is the chemical process of calcimining limestone to lime in the cement kiln also produces carbon dioxide. In India about 2,069,738 thousands of metric tons of carbon dioxide was emitted in the year of 2015. The cement industry contributes about 5% of total global carbon dioxide emissions. The cement is manufactured by using the raw materials such as limestone, clay and other minerals by procuring them by quarrying process which also causes environmental degradation. To produce 1 ton of cement, about 1.6 tons of raw materials are required and the time taken to form the lime stone is much longer than the rate at which humans use it.

Aggregate is the main constituent of concrete, occupying more than 70% of the concrete matrix. River Sand or natural sand is most common form of fine aggregate used in the manufacturing of concrete. In many countries, there is a scarcity of natural aggregate that is suitable for construction due to increased cost and large scale depletion of sources, whereas in other countries the consumption of aggregate has increased in recent years, due to increases in the construction industry. In order to reduce depletion of natural aggregates due to construction, artificially manufactured aggregate and some industrial waste materials can be used as alternatives. Many alternative materials with similar physical & chemical properties of sand are found and studies have been carried out to check the suitability of its use as partial replacement of sand.

On one side there is pollution caused due to cement production and there is depletion in the amount of sand and on the other side, the demand of concrete is increasing day by day for its ease of preparing and fabricating in all sorts of convenient shapes. So to overcome this problem, the concrete to be used should be environmental friendly. To produce environmental friendly concrete, it is necessary to replace the cement and fine aggregates with the industrial products such as Micro Silica (MS) and Copper Slag (CS) respectively.

Due to increase in industries, generation of industrial by-products was also increased. Micro Silica and Copper Slag are such by-products. Micro Silica is an ultrafine powder, and is light to dark grey in color. It is a co-product from the silicon or ferrosilicon industry and rich in silicon dioxide (SiO_2). When added to concrete improves the characteristics of concrete in two ways. Firstly due to its pozzolanic nature, chemically reacts with the calcium hydroxide leached out during the cement hydration leading to the increase in the amount of calcium silicate hydrate gel, thus improving the strength of the concrete. Secondly being an ultra-fine material physically fills the voids between cement particles making the concrete dense thus imparting water tightness

and impermeability. Copper slag (CS), the glassy material, produced during matte smelting and copper conversion was previously considered waste and disposed as landfill. It has been estimated that for every ton of copper production about 2.2-3 tons Cement-cement is a binder, a substance that sets and hardens and can bind other materials together. Though all cement conforming to various IS code is suitable, selection of cement should be based on their compressive strength, fineness and compatibility with other ingredients and durability requirements.

Slag are generated. Slags containing < 0.8% copper are either discarded as waste or sold cheaply. This will help in resolving a major concern of industrial waste disposal along with decreased cost of construction.

II. OBJECTIVES

- We here make use of Micro Silica, a waste product from Metal manufacturing industry and copper slag, a by-product during copper smelting and refining process from for designing M50 grade concrete for overlays.
- Proportioning and mix design of Control concrete & Ordinary Portland Cement (OPC) with sand as per IS10262-2009 for M50 grade concrete.
- To determine various properties like compression strength and flexural strength of control concrete, micro silica and copper slag replaced concrete at varying percentages.

III. MATERIALS AND METHOD

Table 1: Physical Properties of Cement

PROPERTY	VALUE
Specific gravity	3.15
Initial setting time	48 min
Final setting time	345 min
Fineness of cement	2%

As per IS 269: 2013, the results are within maximum limits.

MICRO SILICA- Micro silica is a by-product of silicon metal manufacturing and ferro-silicon alloys. Micro silica consists of spherical particles of an almost pure silicon dioxide which are approximately 0.00015mm in diameter. These are 100 times smaller than the particles of cement. The main advantages of using micro silica are that, when used with super plasticizers, it is possible to obtain good strengths at lower temperatures. Micro silica used in this study was brought from ManjeshwaraTechnotraders, Mangalore, Karnataka, India.

Table 2: Physical Properties of Micro Silica

PROPERTY	VALUES
Moisture	3%
Specific Gravity	2.22
Bulk Density	550-700kg/m^3
SiO_2	85%

FINE AGGREGATE- Natural sand which is used for the concreting purpose must be clean, inert and free from deleterious materials and have a size passing through 4.75mm sieve size. In this study locally available natural sand of zone II according to IS 383: 1970 is used.

Table 3: Physical Properties of Fine Aggregate

PROPERTY	VALUE
Specific gravity	2.63
Water absorption	0.6%
Fineness modulus	3.116

As per IS 383: 1970, the results are within the maximum limits.

COPPER SLAG: Copper slag is a by-product during 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 number of applications in the building and industrial fields. One advantage of copper slag is the low risk it poses to health and the environment. Copper slag used in this study was obtained from Nirmathi Enterprises, Suratkal, Karnataka India.

Table IV: Physical Properties of Copper Slag

PROPERTY	VALUE
Specific gravity	3.5
Water absorption	0.2%
SiO_2	35%
Bulk density	1.8gm/cc

COARSE AGGREGATE- Coarse aggregate are in the form of irregular broken stone or naturally occurring gravel. Material which are large to be retained on 4.75mm sieve size are called coarse aggregates. Locally available coarse aggregate passing through 20mm sieve and retained on 4.75mm sieve were used for this study.

Table V : Physical Properties of Coarse Aggregates

PROPERTY	VALUE
Type and zone	Zone II
Specific gravity	2.665
Water absorption	0.5%
Fineness modulus	3.20

As per IS 383: 1970, the results are within the maximum limits.

WATER – Water to be used in mixing of concrete should be clean and fit for drinking. Potable water is used as per IS 456: 2000 for casting and curing of specimen.

MIX DESIGN: Mix proportioning for M50 grade of concrete is performed using IS 10262:2009 and IS456: 2000 for strength and durability requirements. Mix proportioning for conventional control concrete and with replacement of cement with micro silica and fine aggregate with copper slag is performed.

Mix Proportion is **1:1.47:3.04: 0.4**

IV. RESULTS AND DISCUSSION

A. COMPRESSION STRENGTH

The specimens containing different percentage of micro silica and copper slag were tested in the compressive strength testing machine after 7 and 28 days of curing process. The results are given below in the table and the results are illustrated in the Figure-1.

Table VI: Compressive Strength of Concrete

TYPE OF MIX	7DAYS STRENGTH (N/mm^2)	28DAYS STRENGTH (N/mm^2)
CC	41.92	58.30
3%MS, 20% CS	40.44	48.88
3%MS, 40% CS	44.66	48.6
3%MS, 60% CS	43.55	47.55
6%MS, 20% CS	46.21	55.40
6%MS, 40% CS	42.06	50.36
6%MS, 60% CS	49.92	56.44
9%MS, 20% CS	39.99	51.10

9%MS, 40% CS	40.88	51.55
9%MS, 60% CS	45.62	56.88
12%MS,20%CS	41.63	54.96
12%MS,40%CS	43.7	60
12%MS.60%CS	49.62	58.36

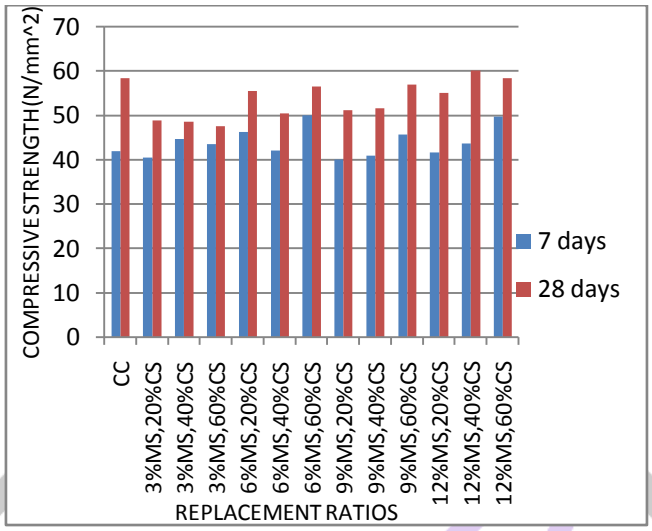

Fig 1: From the graph it is found that 6%MS, 60%CS has attained the maximum compressive strength for both 7 days and 12%MS, 40%CS has attained the maximum compressive strength for 28 days

B. FLEXURAL STRENGTH

Beam of size 700mm x 150mm x 150mm were cast and cured for 28 days. The specimens were placed in the flexural testing machine in such a manner that, the load is applied to the upper most surface as cast in the mould, along two lined spaced 20cm apart. The results are given below in the table and the results are illustrated in the Figure-2.

Table VII : Flexural Strength of Concrete

TYPE OF MIX	FLEXURAL STRENGTH(N/mm^2)
CC	7.28
3% MS, 20% CS	5.33
3% MS, 40% CS	6.311
3% MS, 60% CS	6.22
6% MS, 20% CS	6.57
6% MS, 40% CS	6.22
6% MS, 60% CS	6.13
9% MS, 20% CS	6.00
9% MS, 40% CS	6.4
9% MS, 60% CS	6.75
12% MS, 20% CS	6.4
12% MS, 40% CS	6.22

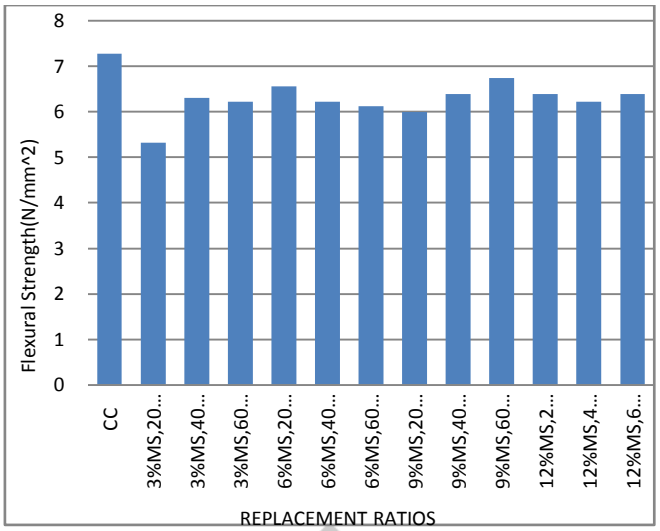

Fig 2: It is observed that 9%MS, 60%CS has attained maximum flexural strength for 28 days.

V. CONCLUSION

A Comprehensive study on micro silica and copper slag based on concrete blocks was conducted to find out whether the micro silica, copper slag based concrete blocks possess desirable engineering properties and also meet the codal provisions. It has been observed that:

1. With increase in percentage of replacement by MicroSilica and Copper Slag the workability also increases.
2. The concrete with 12% replacement by Micro Silica along with 40% replacement of Copper Slag and 2% super plasticizers at the age of 28 days gave the maximum compressive strength i.e. 60 MPa.
3. The concrete with 9% replacement by Micro Silica along with 60% replacement of Copper Slag and 2% super plasticizers at the age of 28 days gave the maximum flexural strength i.e. 6.75 MPa.

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