IMPORTANCE OF FOREIGN MATERIALS IN IMPROVING THE STRENGTH OF CONCRETE

S.T. Devi Suhanya, K.Devika, S.Rajalakshmi, R.Shanmuga Priya
Assistant Professor, Department of Civil Engineering, Peri Institute of Technology, Chennai, Tamilnadu.

***Abstract*— The experimental behaviour of M20 concrete in which the fine aggregate is partially replaced by Copper Slag is studied. Replacing fine aggregate with copper slag makes the concrete cost effective and imparts high strength. The amount of carbon dioxide (CO2) released into the environment during the production of Portland cement can be reduced. Copper slag is one of the materials that is considered as a waste material which could have a promising future in construction industry as partial substitute of either cement or aggregates. M20 grade concrete was used and the tests were conducted for various proportions of copper slag replacement with sand of 0%, 20%, 40%, and 60%, cement of 0%, 5%, 15% and 20% and combination of both (60% sand + 40% copper slag for fine aggregate and 85% cement+15% copper slag for cement) in concrete. The obtained results were compared with those of control concrete made with ordinary Portland cement and sand.**

***Index Terms*— Copper Slag, Sustainability, Carbon di-oxide, Cement, Aggregates, compressive strength, split tensile strength**

I. INTRODUCTION

Concrete is a widely used construction material for various types of structures due to its durability. For a long time it was considered to be very durable material requiring a little or no maintenance. . Many environmental phenomena are known significantly the durability of reinforced concrete structures. We build concrete structures in highly polluted urban and industrial areas, aggressive marine environments and many other hostile conditions where other materials of construction are found to be nondurable. The use of concrete is unavoidable. At the same time the scarcity of aggregates are also greatly increased nowadays.

Utilization of industrial soil waste or secondary materials has been encouraged in construction field for the production of cement and concrete because it contributes to reducing the consumption of natural resources. For many years, by products such as fly ash, silica fume and slag were considered as waste materials. Copper slag is widely used in the sand blasting industry and it has been used in the manufacture of abrasive tools.

About 1.5 tons of raw materials is needed in the production of every ton of PC, at the same time, about one ton of carbon dioxide (CO_2) is released into the environment during the production. Concrete made of PC deteriorates when exposed to the severe environments, either under the normal or severe conditions. Hence the cement is partially or fully replaced by some Magnesium Phosphate cement (MPC), Ground Granulated Blast Furnace Slag, Silica Fume, supplementary cementitious materials like Fly Ash, Non Ferrous Slag, Geopolymer, and Natural Pozzolans.

Supplementary cementitious materials are used to improve a particular concrete property. Supplementary cementitious materials are used in at least 60% of ready mixed concrete. Many supplementary cementing materials resemble the color of Portland cement. All supplementary cementitious materials may not be available in all areas. In most cases, moisture will not affect the physical performance of supplementary cementitious materials. These materials are usually kept in bulk storage facilities or silo, although some products are available in bags. Air-cooled nickel slag is evaluated for highway construction applications as an aggregate in hot mix asphalt.

II. EXPERIMENTAL PROGRAM

Ground granulated blast-furnace

It is also called slag cement, made from iron blast furnace slag. Ground granulated blast-furnace slag was first developed in Germany in 1853.

Silica fume

It is also known as micro silica or condensed silica fume which is used as by-product material which is used as a pozzoloan. The relative density of silica fume ranges between 2.20-2.5 and the bulk density varies from 130 to 430 kg/m3. Although they can be used in normal construction they are often used in building bridges and parking garages. Silica fume is sold in powder form but most commonly.

Non Ferrous Slag as construction material

A non-ferrous slag from the production of metallic zinc was studied as a new ingredient for concrete. It was used in two forms: ground and unground material. The ground slag replaced 15% of Portland cement, whereas the un-ground slag replaced 20% of the natural sand. The workability of concrete is generally improved by adding Fly ash, Slag and Shale. The heat of hydration will be low in the case of Fly ash and ground slag when compared with Portland cement. The use of fly ash will generally retard the setting time of concrete.

III. CONCRETE MIX DESIGN

A. Mix Design for M20 mix

Concrete mix designs is best defined as a process in selecting suitable ingredients, which is cement, aggregate, sand and water, and determining their relative proportions to give the required strength, workability and durability. The mix designs, which is a performance specification stating required strength and minimum cement content but leaving the grading and details of the concrete mix design to be work out.

B.Theory of Mix Designs

The method of concrete mix design applied here is in accordance to the method published by the Department of Environment, United Kingdom (in year 1988).

1. Specified variables; the values that are usually found in specifications.
2. Additional information, the values normally available from the material supplier.
3. Reference data consists of published figures and tables is required to determine the design values including;
4. Mix parameters such as target mean strength, water-cement ratio and concrete density.
5. Unit proportions such as the weight of materials.

The design process can be divided into 5 primary stages. Each stage deals with a particular aspect of the concrete mix design:

Stage 1: Determining the Free Water/

Cement Ratio

i) Specify the required characteristic strength at a specified age, f_c

ii) Calculate the margin, M.

$M = k \times s$ ….. (1)

where;

k = A value appropriate to the defect percentage permitted below the characteristic strength. [k = 1.64 for 5 % defect]

s = The standard deviation (obtained from CCS 1).

Approximate compressive strength (N/mm2) of concrete mixes made with a free-water/cement ratio of 0.5

iii) Calculate the target mean strength, f_m

$f_m = f_c + M$ ….. (2)

where;

f_m = Target mean strength

f_c = The specified characteristic strength

iv) Given the type of cement and aggregate, use the table of CCS 1 to obtain the compressive strength, at the specified age that corresponds to a free water/cement ratio of 0.

Table I Mix Proportions for M20 Grade

Water (Kg/m^3)	Cement(Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)
191.6 0.5	383 1	727 1.9	1103 2.8

Table II Test results of cement

SL.NO	DESCRIPTIONS	OPC(53 GRADE)
1	Fineness (m2/kg)	274
2	Normal Consistency (%)	32%
3	Setting Time(minutes) a)Initial b) Final	 30 min 600 min
4	Compressive Strength a) 7 days b)28 days	 36 N/mm^2 53 N/mm^2

Applications of Copper Slag

Slag has already been recognised world-wide, are cement and concrete manufacturing, filling material, river embankment, ballast material, abrasive, pavement blocks, road and roofing construction, granules, glass and tiles making. Sterlite has carried out several technical studies for the last 10 years through various laboratories on the physical and chemical properties. These studies have concluded that copper slag is non-leachable, and non-toxic. In Singapore, copper slag is largely used as abrasive for the removal of rust and marine deposits that have accumulated on ships. Spent copper slag originates from raw copper slag that has been spent of its abrasive property after using it to remove rust and marine deposit from ships. If the spent copper slag is properly treated to reduce the contaminant to an acceptable level, it can be further re-used. The treated spent copper slag can be recycled and put to good use as sand replacement in concrete. For structural usage, the use of copper slag as partial replacement of sand in concrete is allowed for up to 10% by mass. Tests have to be conducted to ensure that chloride and sulphate contents in the slag are within the allowable limits. The technology and process will involve the treatment and re-constitution of the spent copper slag to satisfy all the requirements for its use in making concrete.

Copper Slag Aggregates with Normal Aggregate

Gradation*:*Copper slags can be crushed andit satisfies the gradation requirements for granular aggregates.

Durability: Copper slag aggregates displayvery good soundness (resisting freeze-thaw deterioration), are harder than conventional granular aggregates and have good resistance to wear.

Stability: The high angularity and friction angle (up to 53°) of copper slag aggregates contribute to excellent stability and load bearing capacity.

Drainage Characteristics: Copper slag aggregates tend to be free draining and are not frost susceptible. The use of copper slag aggregate compared to limestone aggregate resulted in a 28-day compressive strength increase of about 10-15%, and a splitting tensile strength increase of 10-18%.

Water absorption for CS was 0.40% when compared with 0.70% for sand. This suggests that CS has less apparent porosity and would demand less water than that required by sand in the concrete mix. Therefore due to higher free water content in concrete mix and also due to the higher coarseness of CS.

Copper Slag Aggregates with Normal Aggregate

Gradation*:* Copper slags can be crushed and it satisfies the gradation requirements for granular aggregates.

Durability: Copper slag aggregates display very good soundness (resisting freeze-thaw deterioration), are harder than conventional granular aggregates and have good resistance to wear.
Stability: The high angularity and friction angle (up to 53°) of copper slag aggregates contribute to excellent stability and load bearing capacity.
Drainage Characteristics: Copper slag aggregates tend to be free draining and are not frost susceptible. The use of copper slag aggregate compared to limestone aggregate resulted in a 28-day compressive strength increase of about 10-15%, and a splitting tensile strength increase of 10-18%.
Water absorption for CS was 0.40% when compared with 0.70% for sand. This suggests that CS has less apparent porosity and would demand less water than that required by sand in the concrete mix. Therefore due to higher free water content in concrete mix and also due to the higher coarseness of CS the workability of the concrete increase when the CS partially replaces sand.
The amount of bleeding of mortar made with CS is comparatively less than that using natural sand. The presence of silica in slag is about 26% which is desirable since it is one of the constituents of the natural fine aggregate used in normal concreting operations.

IV. RESULTS AND DISCUSSION

A. Modulus of Elasticity

Procedure

Place a cylinder with the compressometer fixed, on the plane of the compression testing machine and apply loading at the rate of 14N/mm2/min. At regular intervals of loading, note the compressometer reading.

Calculate the stress and strain for each reading and draw the stress-strain curve.

Determine the secant modulus of elasticity at 30% of the cube strength.

Table III Modulus of Elasticity of the cubes

S.no	Mix id	Modulus of Elasticity (N/mm^2)
1	0% (Control)	$2.4x10^4$
2	40%	$3.1x10^4$

B. Split Tensile Test on Concrete

Procedure

The length and diameter of the concrete cylinder are measured accurately. The test carried out by placing the cylindrical specimen horizontally between the loading surfaces of a compression testing machine. The load is applied until the failure occurs. The load at which the cylinder fails is noted. Using the formula below the split tensile strength is calculated by 2x(failure load) divided by (3.14xdxl) A ratio of 1:1.5:3 was taken under the grade M20 and the required quantity off each element was mixed thoroughly. The elements were mixed by hand, cement and fine aggregate dry elements were first mixed and then the coarse aggregates. The concrete is poured in moulds oiled with medium viscosity oil. Fill the cylinder mould in four layers each of approximately 75 mm and ram each layer more than 35 times with evenly distributed strokes. Remove the surplus concrete from the top of the moulds with the help of the trowel. Cover the moulds with wet mats and put the identification mark after about 3to 4 hours. Remove the specimens from the mould after 24 hours and immerse them in water for the final curing. The test are usually conducted at the age of 7-28days. The time age shall be calculated from the time of addition of water tithe dry ingredients. Test at least three specimens for each age of 7 days the tensile strength was found to be $3N/mm^2$.

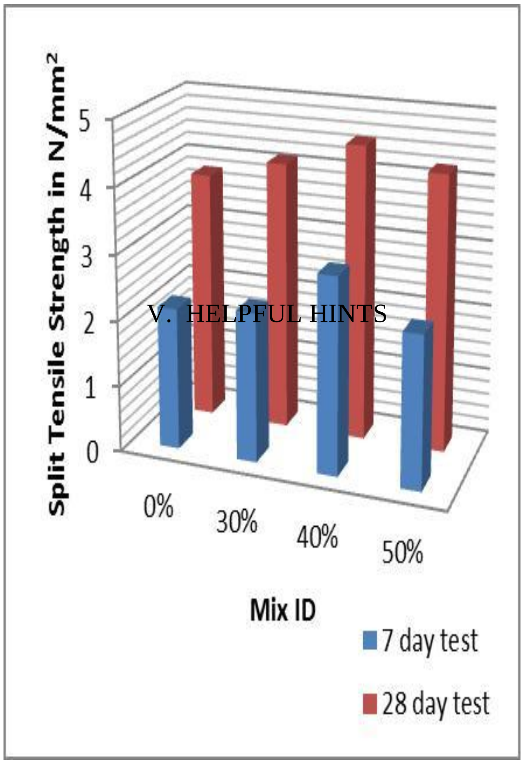

Fig I Bar chart showing the split tensile stresses of concrete

Fig II Split Tensile Test

Table IV SplitTensile Strength for mix id's

0%,30%,40%,50%

Mix id	Mix type	Strength(Mpa)	
		ft7	ft28
0%	Control (100%S)	2.15	3.8
30%	70%S+30%CS	2.26	4.1
40%	60%S+40%CS	2.97	4.5
50%	50%S+50%CS	2.3	4.2

S - Sand , CS - Copper Slag,

f_t7 - Split Tensile Strength, Cured at 7-days

f_t28 - Split Tensile Strength, Cured at 28-days

C. Cube Compression Test

Concrete mixtures should be designed to provide a wide range of mechanical and durability requirements .The compressive strength is the most common performances measured by an engineer in designing a building or a structure. The compressive strength is measured by breaking cylindrical concrete specimens in a compression testing machine. The compressive strength is determined from the failure load divided by the cross sectional area resisting the load and is reported in required units.

This test is undertaken to determine the strength of concrete with direct compressive loading on the surface. The concrete was mixed with a water cement ratio of 0.5.The mix design was done and M20 was used that gave a ratio of 1: 1.5:3 which is cement: fine aggregate: coarse aggregate. The coarse aggregate used in the concrete was sieved that passed through 40 mm and retained on the 20 mm was used. The fine aggregates sieved through 4.25 micron was used with 53 Grade cement. Six cubes in number were casted, each cube of size 15x15x15 cms. Three of them were cured perfectly for a week and then the seventh day test for its compressive strength was tested and a value of the first cube of weight 504kN was 22.4N/m^^{2}, the second cube of weight 418kN was found to have a compressive strength of 18.5 N/m^2 and the third cube of weight 381kN was obtained as 16.93N/m^2. The remaining cubes were cured for another seven days and when tested for its compressive strength a value of 19.266N/m^$_2$ was obtained. Hence since the compressive strength values for the tested concrete cubes shows acceptable values this concrete is tested meets the strength requirements.

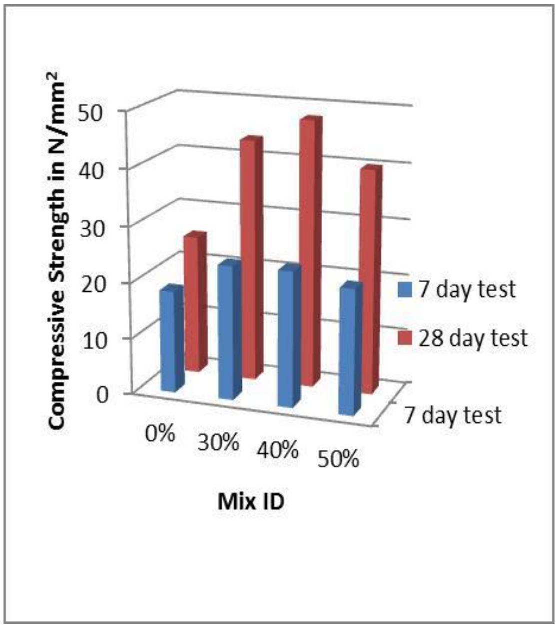

Fig III Bar chart showing the compressive strength of concrete

Table V Compressive Strength Test Results

MIX ID	MIX TYPE	STRENGTH(MPa)	
		fc7	fc28
0%	Control (100%S)	18.35	25.20
30%	70%S+30%CS	24	43.5
40%	60%S+40%CS	24.2	47.8
50%	50%S+50%CS	22.3	40.2

S - Sand, CS - Copper Slag,
fc7 - Cube Compressive Strength, Cured at 7-days
fc28 - Cube Compressive Strength, Cured at 28-days.

V. RESULTS AND DISCUSSIONS

A. Comparison of Results

It has be experimentally found that the highest compressive and tensile strength was obtained when sand was replaced by copper slag by 40%. The results of various tests are tabulated below.

Table VI Results of various tests

Mix id	Compressive strength (N/mm^2)	Tensile strength (N/mm^2)
0% (control)	25.20	3.8
40%	47.80	4.5

VI.CONCLUSIONS

- The behaviour of CS seems to be similar to river sand for its use as fine aggregate in concrete mixes.
- The utilization of copper slag in cement and concrete provides additional environmental as well as technical benefits for all related industries.
- Replacement of copper slag in both fine aggregates and cement replacement reduces the cost of making concrete
- The results of compressive, split tensile strength test have indicated that the strength of concrete increases with respect to the percentage of slag added by weight of fine aggregate up to 40% .

The slump value of copper slag concrete lies between 75 to 100 mm

REFERENCES

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

[2] Ayano T, Sakata K.(2000), Durability of concrete with copper slag fine aggregate, The

5th CANMET/ACI international conference on durability of concrete, pp 141–158.

[3] L. Zong, (2003), The replacement of granulated copper slag for sand concrete, J

Qingdao Inst Architect Eng 24 (2) pp. 20–22.

[4] MostafaKhanzadi, Ali Behnood(2009), Mechanical properties of high-strength concrete incorporating copper slag .