International Journal For Technological Research In Engineering
Volume 9, Issue 10, June-2022 *ISSN (Online): 2347 - 4718*

STUDY OF THE BEHAVIOUR OF THE CONCRETE BY USING COPPER SLAG AND STEEL FIBERS

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Abstract: Many countries around the world are witnessing a rapid growth in the construction industry which involves the use of natural resources for the development of the infrastructure. In order to reduce dependence on natural aggregates as the main source of aggregate in concrete, artificially manufactured aggregate are becoming popular in these days. Artificial aggregates generated from industrial wastes provide an alternative solution to the shortage of aggregate for the construction industry. The rapid growth of technology and population in India, there is a huge demand for construction material mostly for natural sand of late excessive consumption of sand caused ecological imbalances &economical issues. To overcome these effects large modifications are being carried out in construction industry, i.e. usage of by-products as a replacement of fine aggregate. In the present study to increase the mechanical properties of concrete steel fibers are added to the concrete mix. Experimental investigation was carried out to evaluate the mechanical properties of steel fiber reinforced concrete by partial replacement of Fine Aggregate (F.A.) with copper slag for M30 grade concrete. Tests are conducted with 1% addition of hooked end steel fibers having aspect ratio 60 and replacement of F.A by 0%, 10%, 20%, 30%, 40%, 50%, 60%), copper slag. Compressive strength, split tensile silt-nth, and flexural strengths were estimated and presented. It was observed from the above experimental work, that, 50% replacement of fine aggregate with copper slag is optimum.

KEYWORDS: Copper Slag, Steel Fibers, Compressive Strength, Flexural Strength, Split tensile Strength.

1. INTRODUCTION

Concrete is an artificial material in which the aggregates both fine and coarse are bond. too, by the cement when mixed with water. The concrete has become so popular and indispensable because of its inherent in concrete brought a revolution in applications of concrete. Concrete has unlimited opportunities for innovative applications, design and construction techniques. Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a stone-like material. Concrete is used to make pavements, architectural structures, foundations, and motor ways/roads, bridges/overpasses, parking structures, brick/block walls and footings for gates, fences and poles. Its great versatility and relative economy in filling wide range of needs has made it is very competitive building material. Many countries are witnessing a rapid growth in the construction industry which involves the use of natural resources for the development of the infrastructure.

This growth is jeopardized by the lack of natural resources that are available. The sustainable development for construction involves the use of non-conventional and innovative materials, and recycling of waste materials M order to compensate the lack of natural resources and to find alternative ways for conserving the environment. Aggregates are considered one of the main constituents of concrete since they occupy more than 70% of the concrete matrix. Therefore, utilization of aggregates from industrial wastes can be alternative to the natural and artificial aggregates. In the last few decades there has been rapid increase in the production of waste materials and by-products due to the exponential growth rate of population, development of industry and technology and the growth of consumerism. The basic strategies to decrease solid waste disposal problems have been focused at the reduction of w7te production and recovery. of usable materials from waste as raw materials as well as utilization of waste as raw materials whenever possible.

The beneficial use of by-products in concrete technology has been published with regard to the use of materials such as coal fly ash pulverized fuel ash, blast furnace slag and fume as partial replacements for Portland cement With the advancement of technology and increased field of applications of concrete and mortars, the strength workability, durability and other characters of the ordinary concrete need modifications to make it more suitable by situations. Added to this is the necessity io combat the increasing cost and scarcity of cement and aggregates. Under these circumstances the use of admixtures and partial replacement of aggregate with other wastes arc found to be an important alternative solution.

STEEL FIBRES

Steel fibres are defined as short discrete lengths of steel having an aspect ratio front about 20 to 100 according to ACI-544(3R-08). Simi fibers are made of cold drawn steel wire with low content of carbon (C) or stain less steel wire (SS 302/ SS 304). Simi fibers are manufactured in different types: hooked, undulated or flat, according to the construction project. The. fibers arc used in construction, for concrete reinforcement . Fiber-reinforced normal concrete is mostly used for on-ground floors and pavements, but am be considered for a wide range of construction parts (beams, pillars, foundations etc) either alone or with hand-tied rebar.

Features of FRC
• fiber-reinforcement is mainly used in concrete, but can also be used in normal concrete fiber;
• steel fibers reinforced concrete arc I.s expensive than hand tied re bar, while still increasing the tensile strength many times;
• shape, dimension and length of fiber arc important
• a normal size fiber for European concrete (I mm diameter, 0.5mm length -steel) will increase the concrete tensile strength;
• steel fibers can only be used on surfaces Mat can tolerate or avoid corrosion and rust stains;

COMPOSITION OF STEEL FIBRES:
• The composition of steel fibers generally includes carbon steel or stain less steel.
The length dimension range from 6.4mm to 76mm while Mc diameter range from 0.25mm to 0.75mm.

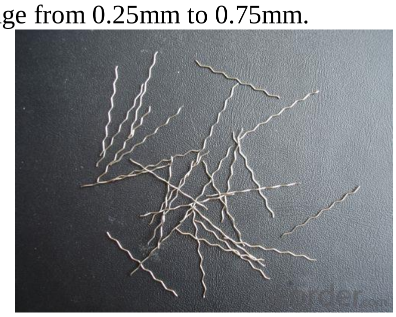

Fig: 1. Steel fibers .

COPPER SLAG
Copper slag is an irregular ,black ,glassy and granular in nature and its properties arc similar to the river sand. Copper slag is used in the concrete as one of the alternative materials. It is the waste product produced in the smelting process during extraction of copper from its ores. slags from or. that are mechanically concentrated before undergoing smelting contain mostly iron oxides and silicon.
Every ton of copper production will generate approximately 2.2-3 tons of copper slag and the safe disposal of this waste is a large, costly and causes environmental pollution. The construction industry is the area where the correct use of waste material (copper slag) is possible. When it is used as a replacement material in concrete, it will reduce the environmental effects, space problem and also reduces the cost of production of concrete.

PHYSICAL PROPERTIES
The specific gravity and density of copper slag a. river sand were determined in accordance with IS2386 part-III. Copper slag has higher density compared with P.A. This may result in production of concrete with greater density. The measured water absorption for copper slag was low compared with sand. This suggests that copper slag has less surface porosity and would require by sand in the concrete mix.

APPLICATIONS OF COPPER SLAG
copper slag is mainly used for surface blast-cleaning. It is used to clean and shape the surface of metal, stone, concrete and other materials and for removal of rust and paints.
• Copper slag can be used in concrete productions as a partial replacement for sand. Copper slag is used as a building material, formed into blocks. Such use was common in areas where smelting was done.

STEEL FIBER REINFORCED CONCRETE
Steel Fiber Reinforced Concrete (SFRC) is composite material comprised of Portland cement, aggregates and steel fibers. Normal unreinforced concrete is brittle with a low tensile strength and strain capacity. The function of the steel fibers distributed randomly is to fill the cracks in the composite Steel Fibers are generally utilized in concrete to control the plastic shrinkage cracking and drying shrinkage cracking. They lessen the permeability and therefore reduce the flow of water. Some types of fibers create greater impact, abrasion and shatter resistance in the concrete. The quantity of fibers required for a concrete mix is normally determined as a percentage addition of the total volume of the composite. The fibers are bonded to the material and allow the FRC to withstand considerable stresses during the post-cracking stage .The actual effort of the fibers is to increase the concrete toughness.

BATCHING OF SFRC
SFRC comprises concrete and steel fibers. The concrete mix is defined in the same way as it the ordinary reinforced concrete. SFRC requires a high quality concrete with a low water cement ratio, good blend of quality aggregates. 'The particular type of steel fibers is chosen in order to achieve specific technical and load-carrying requirements of the SFRC. clement. Concrete mix, fiber type and fiber dosage rate have to be harmonized in order to obtain the best possible solution. It should be noted that the addition of steel fibers will reduce the slump of the concrete. Therefore, in order to ensure the workability, the slump has to be increased by adding plasticizers accordingly if required. Typical dosage rates the steel fibers range from 15 kg/m) (crack control) to 50 kg/m' and sometimes up to 80 kg/m) (structural elements).

ADVANTAGES OF SFRC
Addition fibers into the concrete improves the crack resistance (or ductility) behavior. Traditional re-bars are generally used to increase the tensile strength of the concrete in a provide direction ,whereas steel fibers provides multidirectional reinforcement is one of the reasons steel fibers reinforced concrete successfully replaced weld mesh in lining tunnels.
Less labor is required.
Less construction time is required .
Excellent resistance to corrosion.
Increased tensile, compression, shear and bending strength, in all directions.
Improved ductile behavior after matrix failure.
Improved shrinkage and crack control.
Excellent impact strength.

APPLICATIONS
During recent years, steel fiber reinforced concrete has advanced rather unproven material to one which has now attained acknowledgment in engineering applications.

• Industrial floors for impact resistance and resistance to thermal shock.
• Airport and highway pavements and overlays particularly where a thinner than normal slab is desired.
• Residential buildings for laying foundation slabs.
• Explosion-resistant structures usually in combination with reinforcing bar.
• In short Crete linings for underground support in tunnels and mines.

Other Applications

• Blast or impact resistant structures.
• For laying machine foundations.
• In runways & airport hangars.
• Where hard standings required.
• Precast concrete walls, block, pipes, manhole covers.
• Hydraulic and marine structures durability.
• Defense structures.

TRADITIONAL APPLICATION

• SPRC was initially used as pavements, which has now gained wide acceptance in the construction of heavy - duty and container yard floors in the world due to savings in cost and superior performance during service.
• Applications include building panels, sea defense walls and blocks, piles, blast resistant pipe, highway , kerbs, prefabricated storage tanks, composite panels and ducts. Sprayed in swimming pools is a new application in Australia.

OBJECTIVE OF WORK

The objective of the present work is to evaluate the mechanical properties of steel fiber reinforced concrete by partial replacement of Fine Aggregate (P.A.) with copper slag for M. grade concrete. Tests on concrete are planned to conduct with I% addition Al hooked end steel fibers having aspect ratio 60 and partial replacement of F.A by copper slag with 0%, 10%, 20%, 30%, 40%, 50%, 60%, addition. From the test results the optimum percentage of copper slag will be identified.

2. MATERIALS AND METHODS

In this experimental program, the prim, stage includes the prelim., re-search on selecting the raw materials. Number of conventional trails is prepared and the mix proportions for NI30 grade arc selected by changing different water cement ratios. By replacing the copper slag in 20%, 30%, 40%, 50%, 60% up to where optimum percentage is selected for main trails. The main experimental work involves the addition of steel fibers with 1% by volume of concrete in My, grade. The strength properties arc studied in this work by comparing both grades and also increase of strength in conventional and steel fiber reinforced concrete.

MATERIALS

Concrete is a composition of three raw materials. They are Cement. Fins aggregate and Coarse aggregate. These three raw materials play an important role m manufacturing of concrete. By varying the properties and amount of these materials, the properties of concrete will changes. The main raw materials used in this experimental work are cement, fine aggregate, coarse aggregate, copper slag, and Stood fibers. Ordinary Portland Cement 53 grade, Fine aggregate (20NE-111), Coarse aggregate (20 & 12.5) Trim sits, Potable water, Steel fibers (MSI16035). Copper slag.

CENIENTITIOUS MATERIALS:

CEMENT

Cement is the main ingredient in manufacturing of concrete. The characteristics of concrete will be greatly affected by changing the cement content. The cement used in this project is Ordinary P°n4rid cement of 53 grade confirming to IS 12269 — 1987.

FINE AGGREGATE

Aggregates of size ranges between 0.075mm — 4.75mm are generally considered as fine aggregates. In this experimental work two types of fine aggregate were used. They are River sand and copper slag. The copper slag was used to replace the natural sand. The fine aggregates a. selected as per IS-383 specifications. River Sand it is also called as natural sand. In this work a good quality of natural sand was used. The sand is medium sand and is confirming to Zone-III as per standard specifications.

COPPER SLAG:

Manufactured copper slag used in this process is obtained from nearest crusher unit. The Copper slag is of superior quality and well graded material**.**

Fig: 2. Copper Slag

COARSE AGGREGATE

Aggregates of size more than 4.75mm are generally considered as coarse aggregate. The maximum size of coarse aggregate used M this experimental arc 201nm & 12.5mm. A good quality of coarse aggregates is obtained from nearest crusher unit. The coarse aggregates arc selected as per 1S-383 specifications.

STEEL FIBERS:

Steel fibers used for reinforcing concrete are defined as short, discrete length of steel having an as fixed ratio (ratio of length to diameter) from about 20 to 100 according to AC1-544(31,08). And steel fibers used in the Present study arc hooked end steel fibers type of 0.7mmdia and 35mm length aspect ratio 50.

Fig: 3. Steel Fibres

GENERAL

Mix design is an essential part in manufacturing of concrete. Proper Mix design method gives better properties to the concrete. In this experimental work, the mix design method used is of IS: 10262-2009.

IS METHOD

The Bureau of Indian standards, recommended a set of procedures for design of concrete mix mainly based on the work done in national laboratories. The mix design procedures covered in IS10262-2009. The methods given can be applied for both medium strength and high strength concrete.

DATA FOR MIX APPLICATION

The following data is required for the mix design for IS method

➢ Specific gravity of coarse and fine aggregates
➢ Specific gravity of cement.
➢ Maximum size of coarse aggregate
➢ Standard deviation of compressive strength of concrete

DESIGN STIPULATIONS FOR MIX DESIGN

➢ Grade designation = M30
➢ Type of cement = OPC 53grade conforming to IS2269
➢ Maximum nominal size of aggregate = 20mm
➢ Minimum cement content = 320 kg/m³
➢ Maximum water-cement ratio = 0.45
➢ Workability = 25-75mm
➢ Exposure condition = Moderate
➢ Degree of supervision = Good
➢ Type of aggregate = Crushed angular aggregate
➢ Maximum cement content = 450 kg/m^2
➢ Specific gravity

Fine aggregate = 2.65
Coarse aggregate = 2.7
Cement = 3.07

MIX DESIGN PROCEDURE (As PerIS10262-2009)

MIX DESIGN FOR M30 GRADE

This mix design is adopted after conducting several conventional trails. The final mix design procedure is tabulated as follows.

TARGET STRENGTH FOR MIX PROPORTIONING

Fck-fck + 1.65

Where,
fa-target average compressive strength at 28 days,
fa=characteristic compressive strength at 28 days, and
s = standard deviation.
From Table I, standard deviation, s=5 N/mm2
Target mean strength (f'ck) = 30 +1.65(5)
= 38.25Mpa

SELECTION OF WATER-CEMENT RATIO

From Table 5 of IS 10262: 2009, maximum water-cement ratio = 0.45. Based on experience, adopt water-cement ratio as 0.45. It is not more than 0.45, hence O.K.

SELECTION OF WATER CONTENT

From Table 2 of IS 10262: 2009, maximum water content-186 liter (for 25 to 50 mm slump range)
For 20 mm aggregate
Estimated water content for 50 mm slump-166 liters

CALCULATION OF CEMENT CONTENT

Water-cement ratio = 0.45
Cement content = 166 / 0.45 = 390kg/m^3
From Table 5 of IS 456,
Minimum cement Content for 'severe' exposure condition = 320 kg/m³ 390 kg/m3> 320 kg/m3, hence, O.K.

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

From Table3 of IS 10262: 2009
Volume of C.A. corresponding to 20mm size aggregate and fine aggregate (zone III) for water- cement ratio of 0.45 is 0.64
=0.64+0.044 = 0.684
Volume of Coarse aggregate =0.684
Volume of Fine aggregate =0.316

MIX CALCULATION

Mix calculation for 1 m^3 volume of concrete
Volume of concrete = 1m³
Volume of cement = 0.127 m³
Volume of water = 0.166 m³
Volume of C.A&F.A=0.707
Mass of Coarse aggregate=1297.62Kg/m³
Mass of Fine aggregate=581.852Kg/m³
Mix ratio:
Cement: Fine Aggregate: Coarse Aggregates: water
1 : 1.492 : 3.33 : 0.45

3. RESULTS & DISCUSSION

EXPERIMENTAL RESULTS

The standard dimension of cubes 150mm x 150mm x 150mm is cast and tested to find out the compressive strength for 28 days. The standard dimension of beams 500mm x100mm x 100mm is cast and tested to find out the flexural strength for 28days. The standard dimension of cylinders 300mm x 150mm cast and tested to find out the split tensile strength for 28days. For all these specimens casting moulds are removed for after one day. The removed specimens are placed in the water for 28days for curing purpose. After water cured specimens are taken and allowed to dry under shade, these specimens are tested for compressive strength, flexural strength and split tensile strength for 28days.

The prepared specimens including the material used for preparation of test specimen were tested with metal procedures of concrete testing explained below.

A) Compaction factor test:

All the mixes were evaluated for workability in terms of compaction factor. The compaction factor test apparatus consists of two hoppers, each in the shape of frustum of a cone and one cylinder. The second hopper is smaller than the upper one and is therefore filled to overflowing. The concrete is allowed to fall in to the lower hopper by opening the trap door and then into the cylindrical mould placed at the bottom. Excess concrete across the top of the cylindrical mould is cut and the net weight of the concrete in cylinder is determined. This gives the weight of partially compacted concrete. Then the cylindrical mould is filled with concrete in layers of 5cm depth by compacting each layer fully. The fully compacted weight is then determined and compaction factor (CF) calculated as below. The values are tabulated in Table.

Table 1. Overall result of slump of M30 Concrete

MIX DESIGNATIONS	% of Copper blast & with 1% steel fibres	SLUMP (mm)
M0	0	53
M1	10	55
M2	20	57
M3	30	59
M4	40	61
M5	50	62
M6	60	65

TEST RESULTS and DISCUSSION

TEST RESULTS

This section provides the result obtained from various tests conducted in this work.

EFFECT OF VARIATION OF COPPER SLAG AND STEEL ON COMPRESSIVE STRENGTH

The test was carried out to obtain compressive strength of M30 grade concrete. The compressive strength of concrete is tested for 0%, 10%, 20%, 30%, 40%, 50% and 60% replacement of sand and the values are presented in table and also graphs were plotted below in fig .

Table 2 Overall results of development of compressive strength in M30 concrete with age

PERCENTAGE COPPER SLAG WITH 1% STEEL FIBRE	COMPRESSIVE STRENGTH , MPa
	28 days
0%	44
10%	47
20%	49
30%	50
40%	50.4
50%	51
60%	49.4

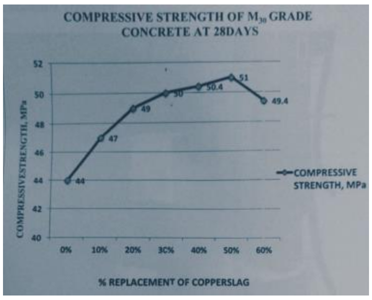

Fig 4. Compressive strength at 28 days for M30 grade of concrete

From both table and graph it is observed that at about 50% replacement of sand with copper slag , concrete attains its maximum compressive strength for M30 grade concretes , when the replacement exceeds 50% the compressive strength is found to be decreasing suddenly at 60% of Copper slag.

4. CONCLUSIONS

Based on experimental observations, the following conclusions are

• As the percentage replacement of copper Slag increases the workability increases**.**

• Compressive strength increases with increase in percentage of copper sing up to 50% and beyond 50% strength decreases at 25 days for Mas grade of concrete.

• Flexural strength also increases with increase in percentage of copper slag up to 50% and beyond 50% strength drops down at 28 days for M30 grade of concrete.

• Split Tensile strength also increases with increase in percentage of copper slag up to 50% and beyond 50% strength drops down at 28 days for Ms grade of concrete

• Considering the strength criteria, replacement of copper slag with fine aggregate is feasible. therefore we can conclude that the utilization of copper slag with steel fibres in concrete is possible.

• Due to low water absorption nature copper slag there is a increase in the workability of conventional concrete when compared with steel fibre reinforced concrete due addition of hooked end steel fibres.

• So addition of hooked end steel fibres increases mechanical properties of concrete and also provides superior resistance to cracking.

• While testing the specimens, the plain cement concrete specimens have shown a typical crack propagation pattern which leaded into splitting of member in 2 piece geometry. But due to addition of steel fibres in concrete cracks gets ceased which results into the flexible behaviour of SFRC.

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