EFFECT OF COPPER SLAG AS A FINE AGGREGATE ON THE PROPERTIES OF HIGH STRENGTH CONCRETE

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ABSTRACT-The present paper explains about the utilization of high volume copper slag in concrete. The study leads towards cleaner production, by utilizing industrial by-product i.e. copper slag as a replacement to natural river sand as fine aggregate. In this literature several studies have highlighted the various aspects of copper slag in developing it as a valuable resource. However there are very limited studies available about the performance of copper slag in high strength concrete. The main aim of the present research is to make the structural high strength concrete by using copper slag. This research work was carried out in two phases to find the strength of concrete. In the first phase the fine aggregate was replaced with copper slag in various percentages of 0%, 20%, 40%, 60%, 80% and 100%. In the second phase, cement was replaced with Nano silica (i.e. 1%, 2%, and 3%) to get maximum strength as well as impermeable concrete. The performance of concrete mixtures containing copper slag and Nano silica in terms of compressive strength, split tensile strength, flexural strength and water absorption were studied. From all these studies it could be determined that high volume copper slag with 100% replacement as fine aggregate in high strength structural concrete is technically viable.

KEYWORDS: **High Strength Concrete (HSC), Copper Slag (CS), Nano Silica (NS).**

1. INTRODUCTION: Concrete is one of the most important material to develop infrastructure in the society. From the past few years there was an increased interest towards high strength concrete among civil and structural engineers to increase the working space in structures and also to reduce the dead weight of structure. High strength concrete having better resistance to fire and less permeable. The expanding commercial use of this relatively new construction material can be explained partially by life cycle cost-performance ratio it offers as well as its outstanding engineering properties and durability properties, when compared to the conventional normal strength concrete. From the historical point of view, the details of high strength concrete are shown in the Table 1.

Table 1: Compressive strength in various years

Year	Compressive strength(MPa)
1930's	25
1960's	40-50
1970's	60
2010	65
2018	>65

As high strength concrete is been widely used throughout the world from the past few decades, in addition to the strength requirement's, workability and durability are considered as important criteria in the production of HSC. In order to meet the above requirements it becomes necessary to use high quantity and quality materials. At present in most of the developmental activities, all across the world, natural resources are being utilized in a huge quantity, which leads to scarcity of natural resources. One of the major constituent utilized in the manufacture of concrete was natural aggregate because it occupies nearly 70% of total volume. It is more expensive to manufacture the aggregates artificially and where as the aggregates which are available naturally will be a far distance from the construction site, in such a case the cost of transportation will be considered as one of the major problem. In the present scenario protecting the natural river sand resource and the shore line is a major concern and to overcome this problem the utilization of natural sand is reduced so that we can prevent the sand mining. There is necessity of utilization of natural resources in the field of construction and to compensate the scarcity of these natural resources there raises the necessity of finding the alternate ways which involves in the utilization of non-conventional and industrial by-products. Copper slag is one such industrial by-product that is considered as a waste material which could have a promising future in construction industry as partial or full substitute of aggregates. To produce one ton of copper, approximately 2.5 to 3.0 tons copper slag is generated as a by-product material. And the present researches have shown that every year nearly 40 million tons of copper slag is produced all around the world and if this copper slag is used properly it can be used as a substitute for natural aggregate and could satisfy the demand of the natural aggregate all over the world.

2. MATERIALS AND METHODOLOGY:

2.1. MATERIALS:

In this work we were use Ordinary Portland Cement of 53 grade (Ultra Tech brand), whose properties are explained in Table 1.

Natural river sand was used as the fine aggregate and copper slag is used as its replacement. As per IS: 383-1970 the natural river sand which is well graded and which comes under zone-2 was used as fine aggregate in the mixes. The detail physical properties of copper slag is explained in the table-3, the natural coarse aggregate which was passed through 12.5mm sieve was used in the mix and the water which was used in the mixes was ordinary tap water. Super plasticizer Glenium B233 which is poly carboxylic ether based is used in all the mixes, specific gravity of super plasticizer was 1.09. Steel fibers whose aspect ratio is 0.60 and whose ends are double hooked at its both ends are been used. Silica fume of specified characteristics is used in all mixes and Nano silica is used in three mixes.

Table 2: Physical properties of cement

Properties	Results
Specific gravity	3.14
Initial setting time	49 min
Final setting time	256 min
Standard consistency	33.26%

Table 3: Physical properties of coarse aggregate

Test	Result
Bulk density	1536 Kg/m^3
Specific gravity	2.808
Crushing value	13.83%
Impact test	11.29%
Elongation index	20.34%
Flakiness index	16.95%

Table 4: Comparison of physical properties between sand and copper slag

Properties	Natural river sand	Copper slag
Color	Light gold color	Black
Sieve size(mm)	0-4.75	0.2-4
Specific gravity	2.63	3.69
Bulk Density(Kg/m^3)	1679	2009
Fineness modulus	2.83	3.16
Zone	2	2
Type of fine aggregate	Medium sand	Coarser
Grain shape	Rounded	Granular, Angular
Water absorption	1.6 to 2%	0.2-0.3%

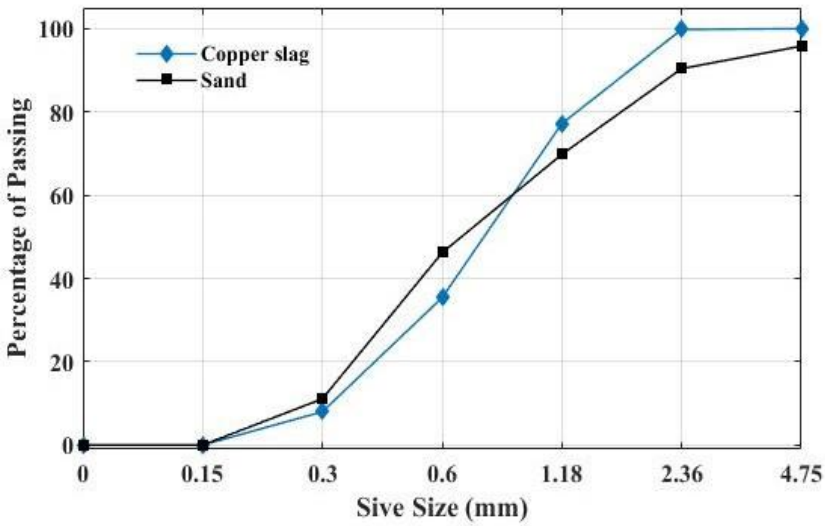

Fig 1: Sieve analysis comparison between sand and copper slag

2.2. EXPERIMENTAL PROCEDURE

2.2.1. MIX PROPORTION AND PREPARATION OF THE SPECIMEN

Till now there are very limited studies available regarding the performance of copper slag in concrete at the structural levels. Numerous scholars carried their analysis about the influence of copper slag in concrete but in the present decade there is necessity to analyze even the durability characteristics of concrete. In the present paper the effects of the copper slag on the mechanical properties and durability characteristic like water absorption of high strength concrete with various percentage replacement of copper slag as fine aggregate was determined. Here, totally nine concrete mixes are prepared. One is nominal conventional mix, five mixes with various percentage of replacement of fine aggregate with copper slag (i.e.20%,40%,60%,80% and 100%) keeping the copper slag as F.A constant and cement is replaced with various percentages of Nano silica (i.e. 1%, 2% and 3%). The various strength characteristics like compression, tensile and flexural properties are identified. The durability characteristic like water absorption test was conducted.

Table 5: Mix proportions of concrete mixes

Mix	Copper Slag %	Cement (Kg/m^3)	Silica Fume (Kg/m^3)	F.A (Kg/m^3)	Copper Slag (Kg/m^3)	C.A (Kg/m^3)	Water (lit/m^3)	SP (lit/m^3)	Steel fibers (Kg/m^3)	Nano Silica (Kg/m^3)
M1	0	548	60.9	695	0	1045	145.8	6.09	11	0
M2	20	548	60.9	556	139	1045	145.8	6.09	11	0
M3	40	548	60.9	417	278	1045	145.8	6.09	11	0
M4	60	548	60.9	278	417	1045	145.8	6.09	11	0
M5	80	548	60.9	139	556	1045	145.8	6.09	11	0
M6	100	548	60.9	0	695	1045	145.8	6.09	11	0
M7	100	542.52	60.9	0	695	1045	145.8	6.09	11	5.48
M8	100	537.04	60.9	0	695	1045	145.8	6.09	11	10.96
M9	100	531.56	60.9	0	695	1045	145.8	6.09	11	16.44

2.3. METHODOLOGY:

2.3.1. COMPRESSIVE STRENGTH:

Compressive strength is a test to indentify the mechanical characteristics of concrete. This test is performed on a 100mmx100mmx100mm size cube specimen. The concrete is casted in the moulds and made to surface dry for one day and then de-molded. Afterwards the cube is cured in water for a period of 28 days.

2.3.2. SPLIT TENSILE TEST:

This test is performed on a cylindrical specimen to evaluate the tensile strength of the concrete. The size of the cylindrical specimen casted in this test was 100mmx200mm.

2.3.3. FLEXURAL STRENGTH:

This test is performed on a beam specimen to identify the flexural behavior of the concrete after 28 days of curing. The size of the beam casted to perform this test was 100mmx100mmx500mm.

2.3.4. WATER ABSORPTION TEST:

The main aim of this test method is to determine density percent of water absorption and to identify the % of voids in the hardened concrete. To perform this test 100*100*100 mm cubes are casted and after 28 days of curing the specimen is made to dry and then this dried specimen is kept in oven at a temperature of 110^0 c for 24 hours, the weight of the specimen is noted as ‘A’ and then the specimen is immersed in water at a temperature of 25^0 c for not less than 48 hours. The weight of the surface dried specimen is noted as ‘B’ and made to boil in water for not less than 5hours, then the specimen is made to cool for a temperature of 20^0c for almost a period of 14 hours and the surface dried weight of the specimen is taken as ‘C’, finally the mass of the specimen is taken by immersing it in the water, this value is noted as ‘D’.

3. RESULTS AND DISCUSSIONS:

3.1. COMPRESSIVE STRENGTH:

After 28 days of curing the strength of the conventional concrete is obtained as 93.93MPa, by keeping this mix as reference the fine aggregate is replaced with various percentages of copper slag .The maximum compressive strength of 100.36MPa is obtained when fine aggregate is replaced with copper at 40%. The least compressive strength of 88.49MPa is obtained when fine aggregate is replaced with 100% copper slag. Now keeping this 100% copper slag mix as constant, Nano silica is replaced with cement in various percentages i.e. 1%, 2% and 3%. The details of the compressive strength results are seen in the table.

Table 6: Compressive strength for various % of copper slag

Concrete mixes	% of replacement of F.A with copper slag	Compressive strength in MPa
mix-1	CS 0%	93.83
mix-2	CS 20%	97.42
mix-3	CS 40%	100.36
mix-4	CS 60%	96.83
mix-5	CS 80%	92.11
mix-6	CS 100%	88.49
mix-7	CS 100%+1% NS	98.66
mix-8	CS 100%+2% NS	90.18
mix-9	CS 100%+3% NS	83.12

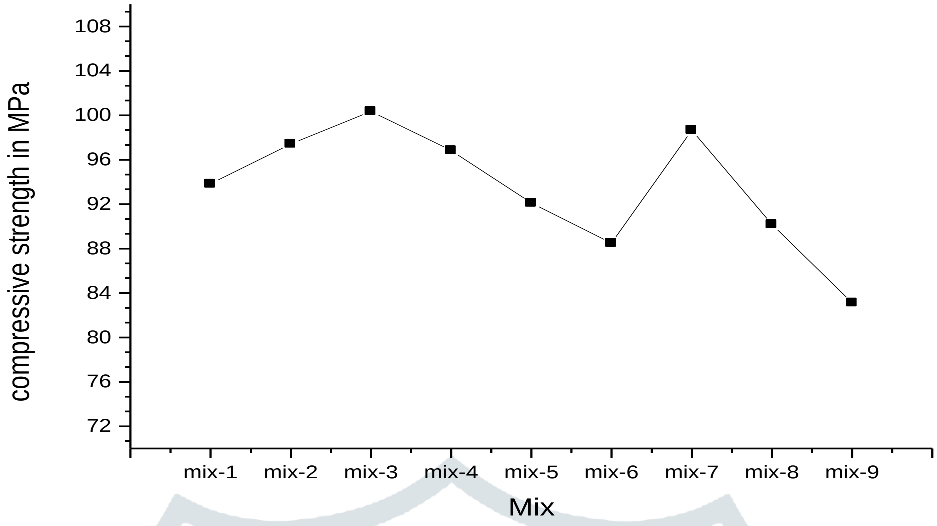

Fig.2: Variation of compressive strength

3.2. SPLIT TENSILE STRENGTH:

The tensile strength of the conventional concrete obtained is 3.98MPa. The maximum tensile strength of 4.76 MPa is obtained in mix-3 (CS 40%). The tensile strength is reduced to 3.69MPa when fine aggregate is replaced with 100% copper slag. Nano silica is replaced with cement in 1%, 2% and 3%. The addition of 1% Nano silica to this 100% copper slag mix improves the tensile strength of concrete to 4.09MPa, where as further addition of Nano silica beyond 1% the tensile strength will be reduced.

Table 7: Split tensile strength for various mixes

Concrete mixes	Proportions	Split tensile strength in MPa
mix-1	CS 0%	3.98
mix-2	CS 20%	4.27
mix-3	CS 40%	4.76
mix-4	CS 60%	4.19
mix-5	CS 80%	3.88
mix-6	CS 100%	3.69
mix-7	CS 100%+1% NS	4.09
mix-8	CS 100%+2% NS	3.83
mix-9	CS 100%+3% NS	3.74

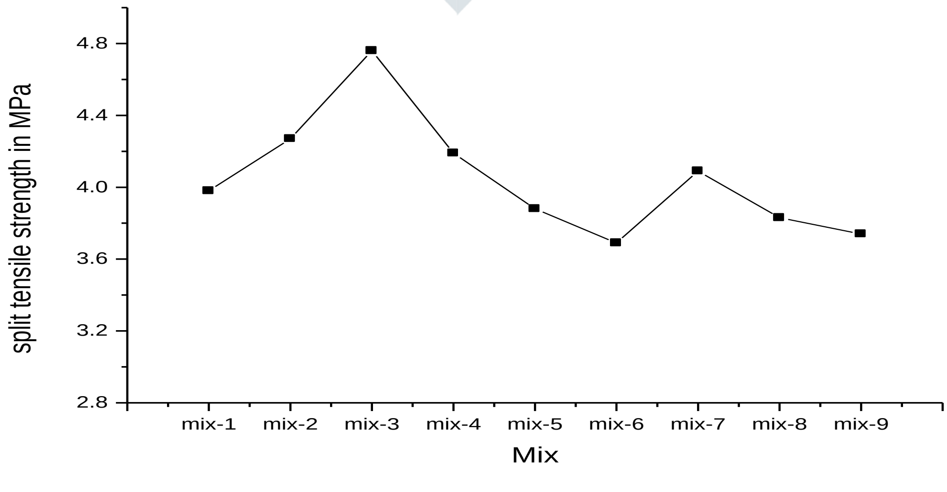

Fig.3: Variation of split tensile strength

3.3. FLEXURAL STRENGTH:

Modulus of rupture strength of conventional concrete obtained was 5.21MPa. The maximum modulus of rupture strength 6.12 MPa is achieved the concrete mix for 40% replacement of sand by copper slag. The least modulus of rupture strength 5.16 MPa is achieved to the concrete mix for 100% replacement of sand by copper slag. The addition of 1% Nano silica to 100% copper slag mix improves the modulus of rupture strength of concrete to 5.49MPa, whereas further addition of Nano silica beyond 1%, the strength will be reduced.

Table 8: Flexural strength for various mixes

Concrete mixes	Proportions	Flexural strength in MPa
mix-1	CS 0%	5.21
mix-2	CS 20%	5.42
mix-3	CS 40%	6.12
mix-4	CS 60%	5.93
mix-5	CS 80%	5.36
mix-6	CS 100%	5.16
mix-7	CS 100%+1% NS	5.49
mix-8	CS 100%+ 2% NS	5.31
mix-9	CS 100%+3% NS	5.16

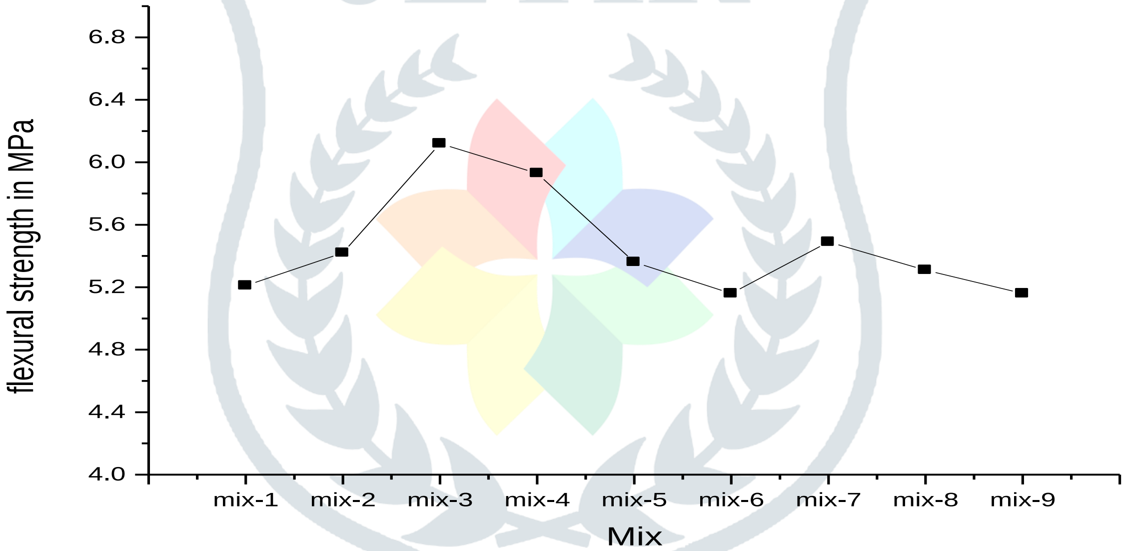

Fig.4: Variation of flexural strength

3.4. WATER ABSORPTION:

The percentage of water absorption for the conventional concrete obtained was 1.62%. When fine aggregate was replaced with copper slag in various percentages i.e. 20%, 40%, 60%, 80% and 100% the percentage of water absorption was reduced. The least percentage of water absorption was seen for the concrete mix where sand is replaced with 100% copper slag. The percentage of water absorption for mix-6 (CS 100%) was 1.98%. By replacement of cement with various percentages of Nano silica the percentage of water absorption will be increased. The details of the water absorption of all mixes were shown in the table

Table 9: Water absorption for concrete mixes

Concrete mixes	Proportions	% of water absorption
mix-1	CS 0%	1.62
mix-2	CS 20%	1.56
mix-3	CS 40%	1.49
mix-4	CS 60%	1.65
mix-5	CS 80%	1.83
mix-6	CS 100%	1.98
mix-7	CS 100%+1% NS	1.45
mix-8	CS 100%+2% NS	1.72
mix-9	CS 100%+3% NS	1.69

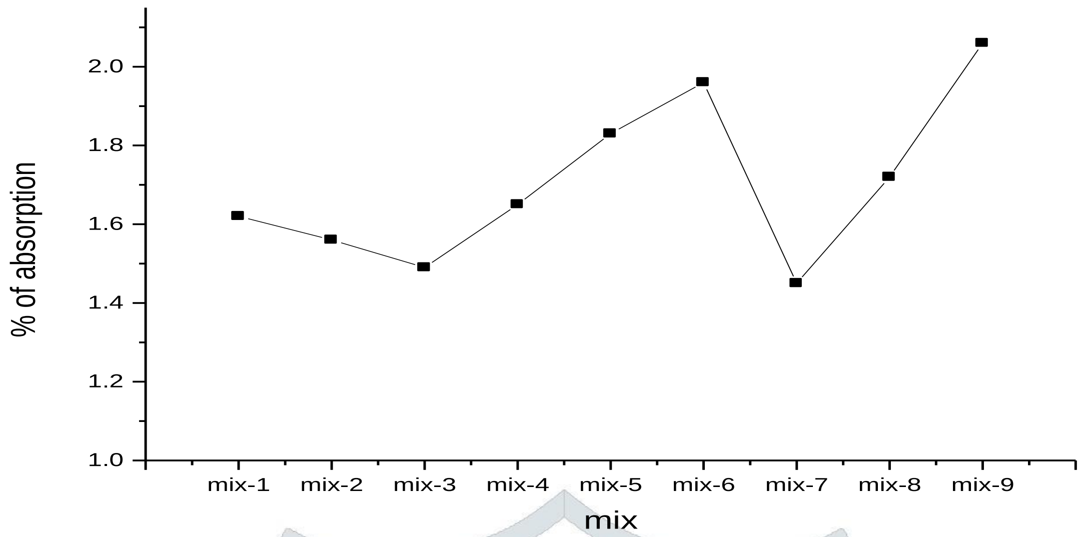

Fig : Variation of water absorption

4. CONCLUSION:

In the present work copper slag used as replacement material for fine aggregate and Nano silica is used as a partial replacement material for cement. According to the results obtained following conclusions can be drawn:

1. The maximum compressive strength of 100.36 MPa is obtained when sand is replaced with 40% copper slag which is more than reference mix. Beyond 40% replacement of copper slag with sand the compressive strength is reduced.
2. When cement is replaced with Nano silica up to 1% in mix-6 (100% CS), the compressive strength was improved from 88.49 MPa to 98.67MPa.
3. The maximum split tensile strength of 4.76 MPa is achieved when sand is replaced with 40% copper slag which is more than reference mix. The tensile strength is reduced with increase in copper slag content.
4. By replacing cement with Nano silica up to 1% with cement in mix-6 (100% CS), the tensile strength is increased from 3.69 MPa to 4.09MPa.
5. The maximum modulus rupture strength of 6.12 MPa is achieved when sand is replaced with 40% copper slag which is more than reference mix. The modulus of rupture strength is reduced with increase in copper slag content.
6. When cement is replaced with Nano silica up to 1% in mix-6 (100% CS), the modulus of rupture strength was improved from 5.16MPa to 5.49MPa.
7. With increase of copper slag content (40%) the percentage of water absorption of concrete was increased.

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