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STUDIES ON THE PROPERTIES OF HIGH STRENGTH CONCRETE WITH COPPER SLAG AS FINE AGGREGATE

K. Mahesh Babu[1], K. Sudhakar Reddy[2]

[1]P.G.Student, Department of Civil Engineering & GPREC,
[2]Assistant Professor, Department of Civil Engineering & GPREC,

Abstract- Utilization of high volume Copper Slag (CS) in concrete is the aim of present work. This study leads towards cleaner production; by utilizing industrial waste i.e. CS. The objective of the present paper is to make High Strength Concrete (HSC) by utilizing CS as Fine Aggregate (F.A). The work was carried in two phases. In first phase, sand was replaced with CS in various percentages of 0%, 20%, 40%, 60%, 80% & 100%. In second phase, cement was replaced with Nano silica (1%, 2% & 3%) to get maximum strength & impermeable concrete. Performance of concrete mixtures containing CS and Nano silica (NS) in terms of compression, split tensile & flexural strength and durability characteristic like water absorption were also identified. From all these studies it could be determined that replacing F.A with 100% CS in HSC was technically viable.

Keywords- High Strength Concrete (HSC), Copper Slag (CS), Nano Silica (NS), Silica Fume (SF), Compressive strength

I. INTRODUCTION:

Concrete is an important part of infrastructure society. From past few years there was an increased interest among structural engineers towards HSC. HSC offers an outstanding mechanical & durability properties, when compared to conventional normal strength concrete. The strength of concrete was varied from decade to decade, from the historical point of view; details of HSC were as follows:

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

As it was observed that there was an increased demand towards the development of HSC. Behalf of strength, workability & durability were also considered as important criteria. Natural aggregate is the major constituent utilized in manufacture of concrete, because it occupies nearly 70% of total volume. It is expensive to manufacture aggregates artificially, where as the aggregates which are available naturally are at far distance from construction site, in such a case transportation cost will be considered as major problem. There is necessity of utilization of natural resources in field of construction and to compensate the scarcity of natural resources, there raises the necessity of finding an alternate, which involves in utilization of non-conventional & industrial wastes. CS is such an industrial waste which has auspicious future in construction field as an alternate to aggregates. And the present researches showed, every year nearly 40 million tons CS is produced all around the world and if this CS was used properly it can be used as a substitute for natural aggregate and satisfy demand of aggregate all over the world.

II. MATERIALS & METHODOLOGY

A. Materials

OPC of 53 grades is used in present work. Natural river sand is used as F.A & CS as its replacement. As per IS: 383-1970, the well graded sand which comes under zone-2 was used as fine aggregate in the mixes. The properties of sand & CS were explained in table-1, the natural coarse aggregate passing through 12.5mm sieve is used in the mix. Poly Carboxylic ether based super plasticizer Glenium B233 was used in all mixes, whose specific gravity was 1.089. SF & NS of specified characteristics were used in mixes.

TABLE 1
PHYSICAL PROPERTIES OF SAND & CS

Properties	Sand	CS
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	Two	Two
F.A type	Medium sand	Coarser
Grain shape	Rounded	Granular, Angular
Water absorption	1.6 to 2%	0.2-0.3%

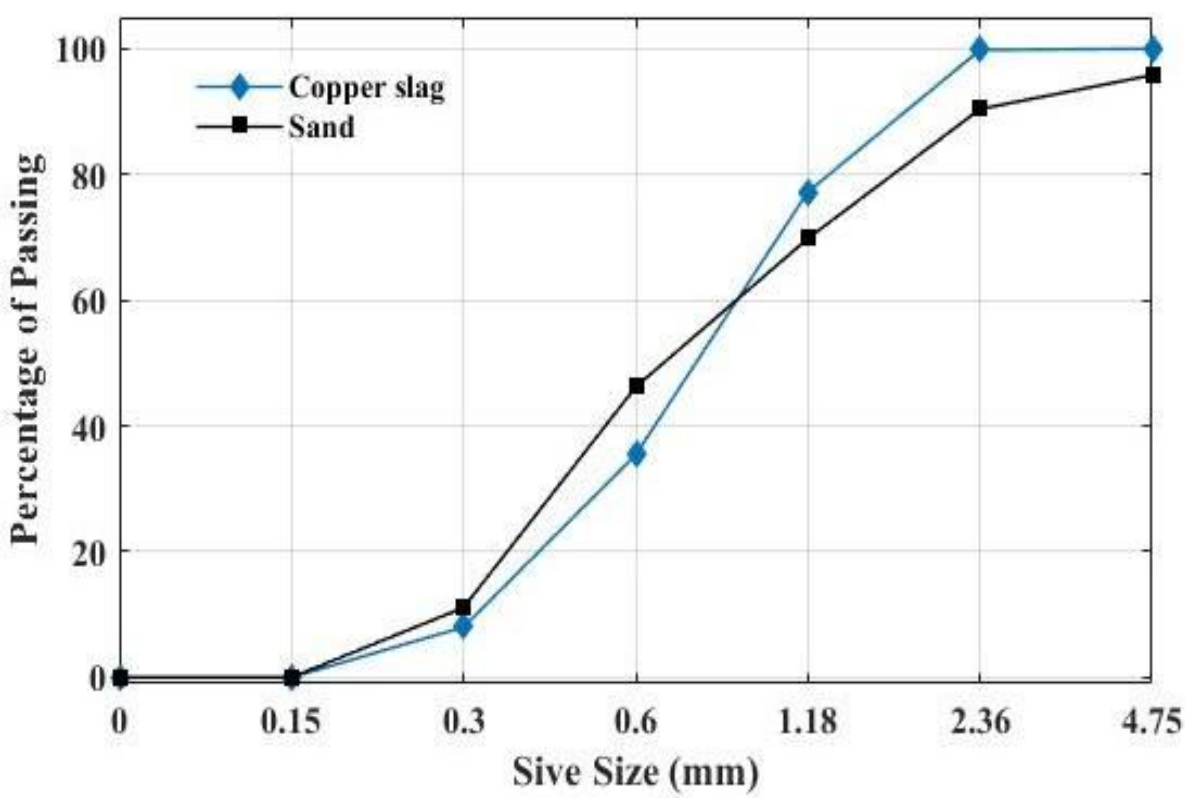

Fig 1: Gradation curve comparison between sand & CS

B. Mix proportion and preparation of the specimen

Very limited studies were available about the performance of CS in concrete at structural level. Numerous scholars carried their analysis about the influence of CS in concrete but in present decade there is necessity to analyze even the workability characteristics of concrete. Present paper explains effects of CS on mechanical properties of HSC. Here, totally nine concrete mixes are prepared. One was nominal conventional mix, five mixes with various percentage of replacement of F.A with CS (i.e.20%, 40%, 60%, 80% and 100%). Keeping the CS as F.A constant, cement was replaced with different percentages of NS (1%, 2% and 3%). Various mechanical characteristics like compression, tensile & flexural behavior of HSC were identified.

TABLE 2
MIX PROPORTIONS OF HSC (M80)

Mix	**CS %**	**Cement Kg/m^3**	**Silica FumeK g/m^3**	**F.A Kg/m^3**	**CS 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	61	695	0	1045	145.8	6.09	11	0
M2	20	548	61	556	139	1045	145.8	6.09	11	0
M3	40	548	61	417	278	1045	145.8	6.09	11	0
M4	60	548	61	278	417	1045	145.8	6.09	11	0
M5	80	548	61	139	556	1045	145.8	6.09	11	0
M6	100	548	61	0	695	1045	145.8	6.09	11	0
M7	100	542.52	61	0	695	1045	145.8	6.09	11	5.48
M8	100	537.04	61	0	695	1045	145.8	6.09	11	10.96
M9	100	531.56	61	0	695	1045	145.8	6.09	11	16.44

C. Methodology

1. *Compression Strength:* Compression strength was a test to indentify the mechanical property of concrete. This test is performed on a 100mmx100mmx100mm size cube specimen. Afterwards, cube was cured for period of 28 days.
2. *Split Tensile Test:* This test was performed on a cylindrical specimen to evaluate the tensile strength. Size of specimen casted was 100mmx200mm.
3. *Flexural Strength:* This test was performed on a beam to identify flexural behavior of concrete after 28 days of curing. The size of the beam casted to perform test was 100mmx100mmx500mm.
4. *Water Absorption Test:* The main aim of test is to determine percent of water absorption in 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'.

% of water absorption = (B-A/A)

III. RESULTS & DISCUSSIONS:

A. Compression Strength

After 28 days of curing the strength of the conventional concrete obtained as 93.83MPa.The maximum compression strength 100.36MPa was obtained when F.A was replaced with 40% CS. The least compression strength of 88.49MPa is obtained when F.A was replaced with 100% CS. Now keeping this 100% CS mix as constant, Nano silica is replaced with cement in different percentages of 1%, 2% and 3%.

TABLE 3
COMPRESSION STRENGTH WITH VARIOUS % OF CS

Concrete mixes	% of replacement of F.A with CS	Compressive strength in MPa
mix-1	CS 0%	93.83
mix-2	CS 20%	97.56
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

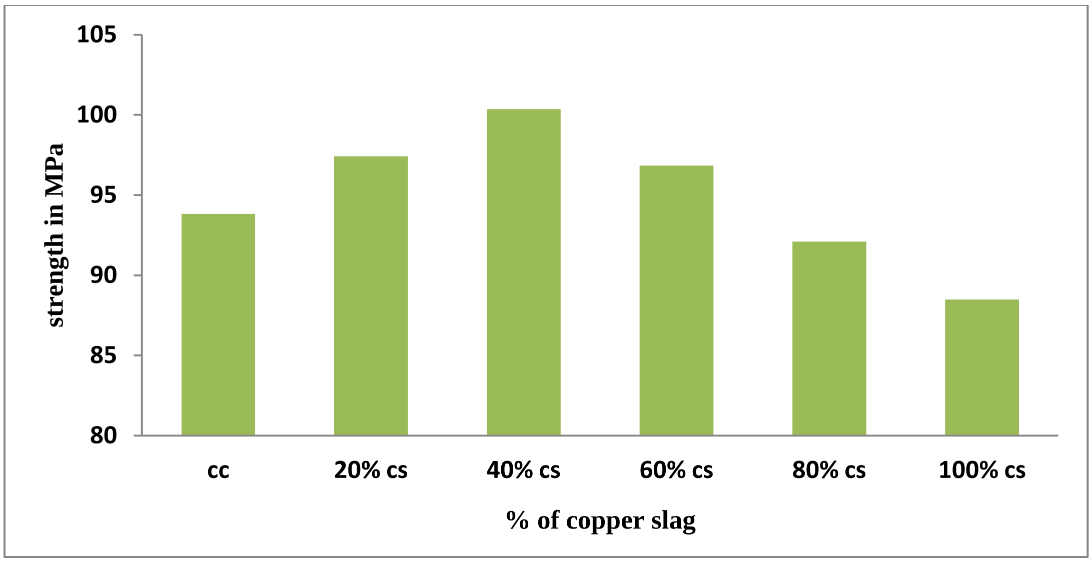

Fig.2: Compressive strength with different % of CS

By replacing cement partially with 1%NS in mix-6 the strength of the concrete was improved from 88.49MPa to 98.66MPa. On further addition of NS beyond 1%, the strength of the concrete was reduced.

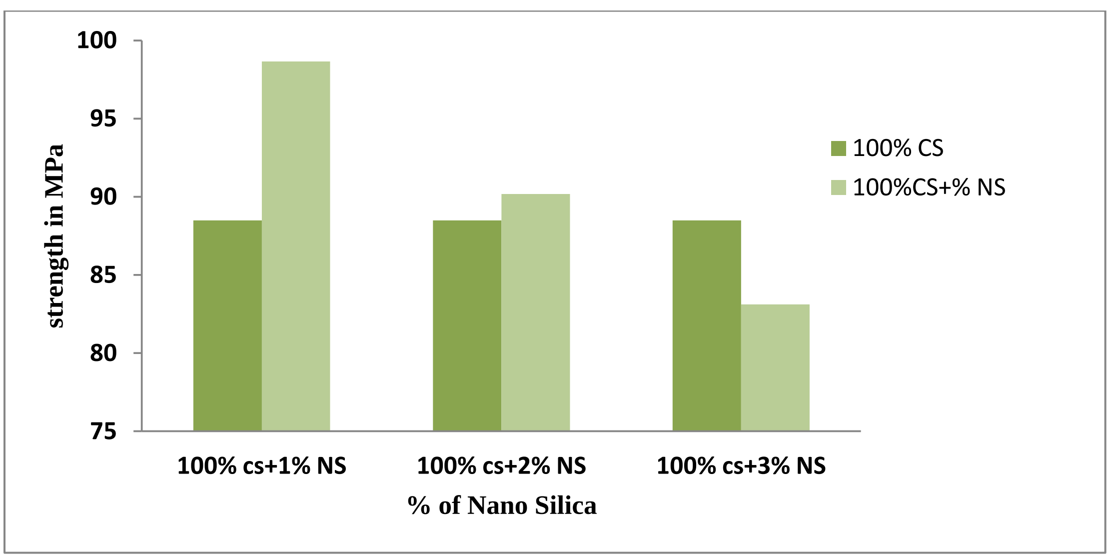

Fig 3: Compressive strength with different % of NS

B. Split Tensile Strength

Tensile strength of the conventional concrete obtained is 5.19MPa. The maximum tensile strength of 5.76 MPa is obtained in mix-3 (CS 40%). Tensile strength is decreased to 4.69MPa when F.A was replaced with 100% CS. NS is replaced with cement in 1%, 2% and 3%. Addition of 1% NS to 100% CS mix improves the tensile strength of concrete to 5.09MPa

TABLE 4
SPLIT TENSILE STRENGTH OF VARIOUS MIXES

Mix	Proportions	Split tensile strength in MPa
mix-1	CS 0%	5.19
mix-2	CS 20%	5.27
mix-3	CS 40%	5.76
mix-4	CS 60%	5.21
mix-5	CS 80%	5.01
mix-6	CS 100%	4.69
mix-7	CS 100%+1% NS	5.09
mix-8	CS 100%+2% NS	4.83
mix-9	CS 100%+3% NS	4.74

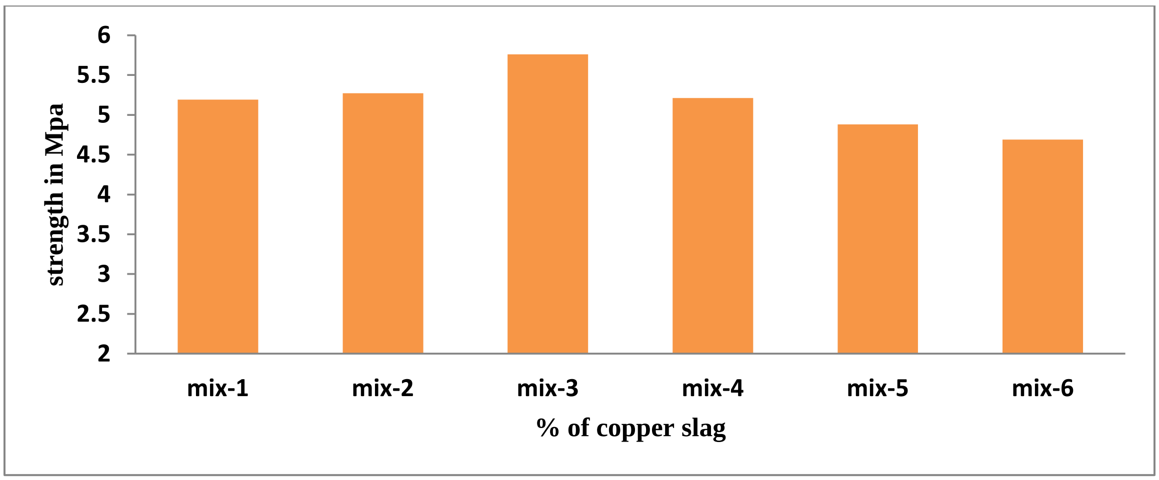

Fig 4: Split tensile strength with different % of CS

By replacing cement partially with 1%NS in mix-6 the tensile strength of the concrete was improved from 4.69 MPa to 5.09 MPa. On further addition of NS beyond 1%, the tensile strength of the concrete was reduced.

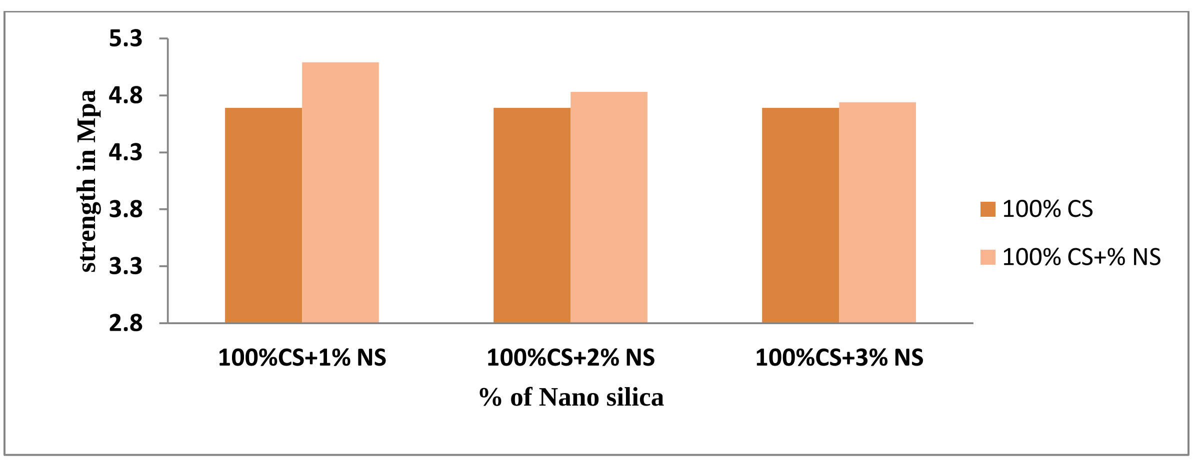

Fig.5: Split tensile strength with different % of NS

C. Flexural Strength

Flexural strength of nominal mix obtained was 6.21MPa. The maximum strength 7.12 MPa is achieved when sand is replaced with 40% CS. The least flexural strength of 6.16 MPa is achieved when sand was replaced with 100% CS. Adding 1% NS to 100% mix-6 improves the flexural strength of concrete to 6.49MPa.

TABLE 5
FLEXURAL STRENGTH OF VARIOUS MIXES

Mix	Proportions	Flexural strength in MPa
mix-1	CS 0%	6.21
mix-2	CS 20%	6.42
mix-3	CS 40%	7.12
mix-4	CS 60%	6.93
mix-5	CS 80%	6.36
mix-6	CS 100%	6.16
mix-7	CS 100%+1% NS	6.49
mix-8	CS 100%+ 2% NS	6.31
mix-9	CS 100%+3% NS	6.10

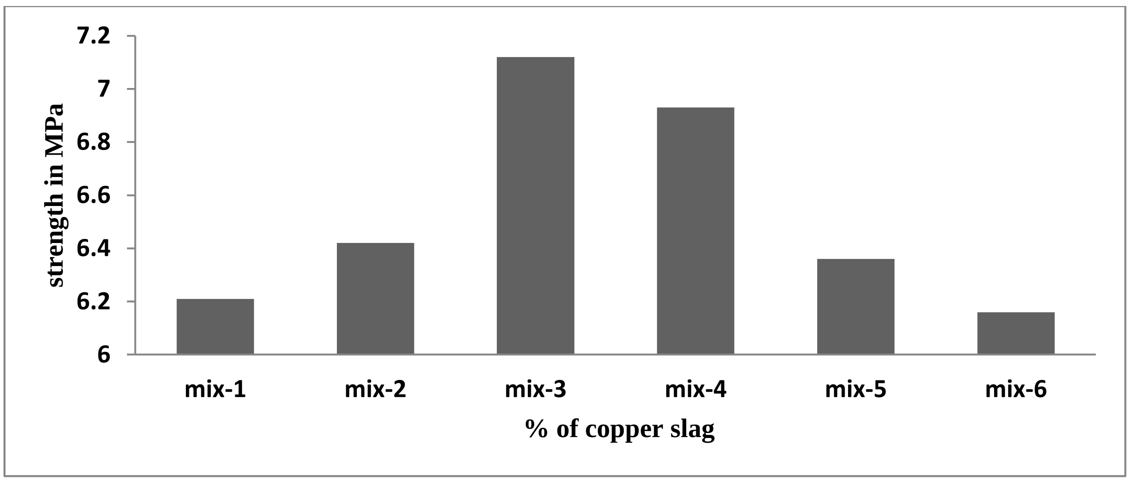

Fig.6: Flexural strength with different % of CS

By replacing cement partially with 1%NS in mix-6 the flexural strength of the concrete was improved from 6.16 MPa to 6.49 MPa. On further addition of NS beyond 1%, the flexural strength of the concrete was reduced.

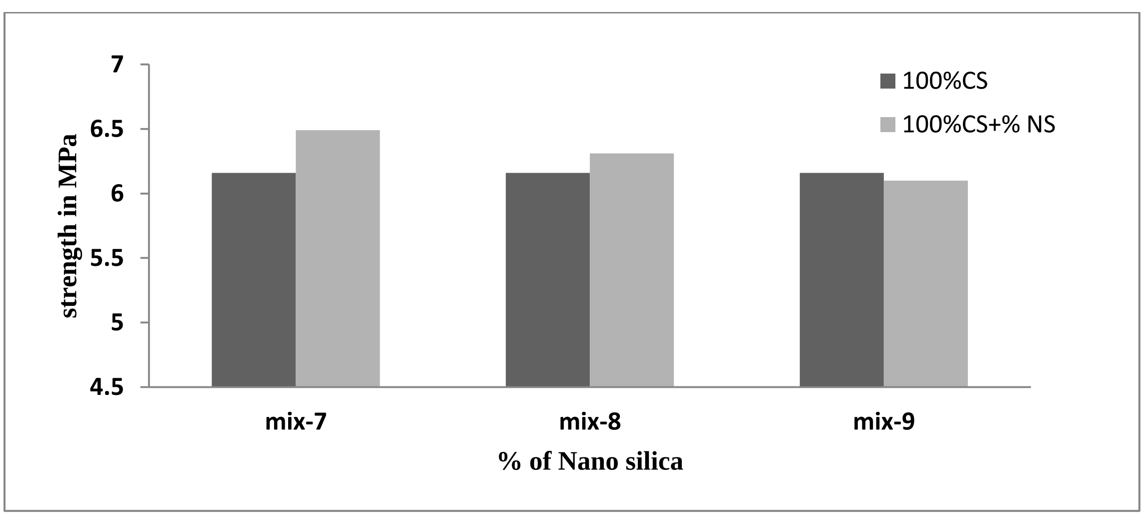

Fig.7: Flexural strength with different % of NS

D. 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% the percentage of water absorption was reduced. The more 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 1.96%. By replacement of cement with various percentages of Nano silica the percentage of water absorption will be increased.

TABLE 6
WATER ABSORPTION FOR CONCRETE MIXES

MIX	PROPORTIONS	% OF WATER ABSORBTION
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%	1.96
mix-7	CS 100%+1% NS	1.45
mix-8	CS 100%+2% NS	1.72
mix-9	CS 100%+3% NS	2.06

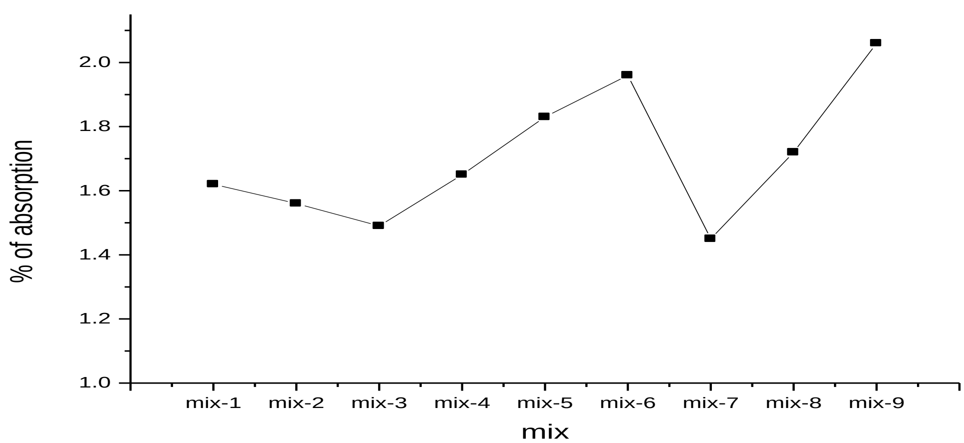

Fig 8: Variation of water absorption

IV. CONCLUSION

Here, in this paper the sand was replaced with different percentages of CS & replacing cement partially with various % of NS improved the mechanical properties of concrete. Following conclusions were drawn from above studies:

- The maximum compression strength of 100.36 MPa is obtained when sand is replaced with 40% CS which was more than reference mix. Beyond 40% replacement of CS with sand the compressive strength is reduced.
- When cement was replaced with 1% NS in mix-6 (100% CS), the compression strength was improved from 88.49 MPa to 98.67MPa.
- The maximum split tensile strength 5.76 MPa was achieved when sand was replaced with 40%CS. The tensile strength was reduced with increase in CS content.
- By replacing cement with 1% NS in mix-6 (100% CS), the tensile strength is increased from 4.69 MPa to 5.09MPa.
- The maximum flexural strength 7.12 MPa is achieved when sand is replaced with 40%CS which was more than reference mix.
- When cement is replaced with 1% NS in mix-6 (100% CS), the flexural strength was improved from 6.16MPa to 6.49MPa.
- With increase of copper slag beyond 40% the % of water absorption was increased

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