

# International Journal of Innovative Research in Science, Engineering and Technology

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## An Experimental Study on HPC by Partially Replacing Natural Sand with Copper Slag & Cement with Nano Silica

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**ABSTRACT:** This paper reports the effect of concrete using copper slag as fine aggregate replacement. In this project work, the concrete grade M40 was selected and IS method was used for mix design. The properties of material for cement, fine aggregate, coarse aggregate and copper slag were studied for mix design. The various strength of concrete like compressive, flexural and split tensile were studied and non-destructive test such as rebound hammer test and ultrasonic pulse velocity measurement were studied for various replacements of fine aggregate using copper slag that are 0%, 20%, 30%, and 40%. The maximum compressive strength of concrete attained at 40% replacement of fine aggregate at 7 and 28 days. The split tensile strength and the flexural strength were also obtained higher strength at 40% replacement level at 28 days. The rebound hammer test showed higher compressive strength at 40% fine aggregate replacement, this is due to uniformity of concrete. The pulse wave velocity is higher for the 40% fine aggregate replacement, it is understood that the density of the mix is high and free from pores.

**Key words:** American society for testing and material (ASTM), Compressive testing machine (CTM), Characteristic Compressive strength of concrete ( $F_{ck}$ ), The European Federation of Specialist Construction Chemicals and Concrete Systems (EFNARC), High Strength concrete (HSC), Superplasticizer (SP).

### I. INTRODUCTION

The construction industry is a major consumer of material and energy sources in the world. Among all the materials used in construction, concrete, which is the most widely used, can have a significant impact. Concrete is considered to be the most widely used construction material. With large scale constructions carried out across the globe, concrete with higher performance was in greater demand. This led to the introduction of high strength and high performance concrete, with the inclusion of several other pozzolanic materials into conventional concrete. It is well known that conventional concrete designed on the basis of compressive strength does not meet many functional requirements such as impermeability, resistance to frost, thermal cracking adequately. High performance concrete (HPC) successfully meets the above requirement.

- Durability in severe environmental (Shorter service life and require maintenance)
- Energy absorption capacity (for earthquake-resistant structures)
- Repair and retrofitting jobs

HPC is an engineered concrete possessing the most desirable properties during fresh as well as hardened concrete stages. HPC is far superior to conventional cement concrete as the ingredients of HPC contribute most optimally and efficiently to the various properties.

High performance concrete (HPC) is a specialized series of concrete designed to provide several benefits in the construction of concrete structures that cannot always be achieved routinely using conventional ingredients, normal mixing and curing practices. In the other words a high performance concrete is a concrete in which certain characteristics are

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developed for a particular application and environment, so that it will give excellent performance in the structure in which it will be placed, in the environment to which it will be exposed, and with the loads to which it will be subjected during its design life.

It includes concrete that provides either substantially improved resistance to environmental influences (durability in service) or substantially increased structural capacity while maintaining adequate durability. It may also include concrete, which significantly reduces construction time without compromising long-term serviceability. While high strength concrete, aims at enhancing strength and consequent advantages owing to improved strength, the term high-performance concrete (HPC) is used to refer to concrete of required performance for the majority of construction applications.

## SCOPE OF THE PROJECT

This work relates to the usage of the copper slag, a waste cheap material used in the concrete. The use of slag partially instead of sand reduces the cost of making cement mortar, as it is a waste available in abundance. Thus, economy in construction can be achieved ultimately.

## DESIRED CHARACTERISTICS OF HPC

The following are the desired Characteristics of HPC,

- Compressive strength should be greater than 70MPa
- Vry early strength (4h) should be greater than 17.5MPa
- Early strength (24h) should be greater than 35MPa
- High impermeability
- High resistance to sulphate attack
- Absence of micro cracking
- High resistance to abrasion, erosion
- High corrosion, electrical and chemical resistivity

## NANO SILICA

Nano means anything of size  $10^{-9}$ , nano-silica particles is a solid particle of having size in the range 1 to 100 nm. Nano-silica has the least particle measures and the most percentage of amorphous silica in contrary to other pozzolan therefore, its reactivity should be higher than other pozzolan. According to its extreme reactivity, the amount of its utilization is much less than other ones. In general, materials in nano measures have totally different, irregular and uncontrolled treatments. As the size of particles shrinks, their qualities will be changed too.

The figure also shows the range at which nano engineered concrete falls in; it can be seen that nano silica particles which has a very high specific surface area, increases the range of the particle size distribution of concrete up to about 5nm level.

Because of its extremely fine nature and high reactivity pozzolanic material, nanosilica has been used to improve slurry impermeability and the mechanical properties of the hardened material.



Fig:1 Nano Silica

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**Table :1 Properties of Nano Silica**

Test item	Standard Requirement	Test Result
Specific surface area (m <sup>2</sup> /g)	200-210	202
Ph value	3.7 – 4.5	4.12
Loss on drying @ 105° c(5)	< 1.5	0.47
Loss of ignition @ 1000° c(%)	< 2.0	0.66
Sieve residue (5)	< 0.04	0.02
SiO <sub>2</sub> Content	➤ 99.8	99.88
Carbon content	< 0.15	0.06

## COPPER SLAG

Copper slag is one of the waste materials that could have a promising future in construction industry as partial or full substitute of either cement or aggregates. It is a by-product obtained during the smelting and refining of copper. For every tons of copper production, approximately 2 tons of copper slag is generated as a waste material. In India approximately 8 lakhs tons of copper slag is produced per annum.



**Fig:2 Copper Slag**

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**Table 2: Properties of fine and coarse aggregate and copper slag**

Test	Fine aggregate	Copper slag	Coarse aggregate
Specific gravity	2.47	3.45	2.68
Fineness modulus	2.89	3.84	7.09
Moisture content (%)	0.1	0.1	0.1
Water absorption (%)	1.2	0.4	1.0
Density (loose state) (kg/m <sup>3</sup> )	1700.67	2197	1513

## OBJECTIVES

- To determine workability and cement concrete with addition copper slag and nano silica.
- To find compressive strength of cement concrete with addition copper slag and nano silica.
- To compute split test cement concrete with addition copper slag and nano silica.

## II. METHODOLOGY

In this investigation, ACI 211.4R.93 method of mix design was used for arriving mix proportions of HPC samples. The slump value for the designed M60 concrete fixed as 25 to 50mm. To check the workability, the slump test was done for various trial mixes. For checking the strength property, cubes were cast and compressive test was done. Based on the above test results, the optimum mix proportion of (1:0.82:2.07) was fixed for both Nano Silica and Copper slag incorporated High Performance Concrete specimens.

Having the above mix proportion as the base of this investigation, nano silica is partially replaced for cement under various percentage such as 1%, 2%, 3%, in addition to that partial replacements of copper slag for sand is made for 10%, 20%, 30%, 40%. The fresh properties of various HPC samples are found using workability tests such as slump test, compaction factor test and Vee Bee consistometer test. The hardened properties including mechanical and also durability properties are studied by conducting respective tests.

## III. DISCUSSION ON RESULTS

### 3.1. Workability of concrete

The workability results are given in table 5.1 for various M60 concrete mixes. In this, the workability of concrete is affected by the various factors such as nano silica, copper slag and super plasticizers. Whenever increasing

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the % of nano silica it reduces the workability, at the same time % increment of copper slag increases the workability. To maintain a constant slump value of 25 mm - 50 mm, the % of super plasticizers is kept as 0.3%, 0.4% ,0.5% for 1%, 2% and 3% replacement of NS respectively. The workability results are shown in fig

**Table: 3 Workability Test Results**

Specimen  Id	W/B  ratio	% of  SP	Workability in terms of		
			Slump in  mm	Compa ction  factor	Vee Bee Degre es  in sec
B1C10	0.31	0.3	28	0.82	10
B1C20	0.31	0.3	34	0.85	14
B1C30	0.31	0.3	40	0.88	20
B1C40	0.31	0.3	43	0.89	28
B2C10	0.31	0.4	32	0.84	12
B2C20	0.31	0.4	39	0.88	19
B2C30	0.31	0.4	47	0.91	27
B2C40	0.31	0.4	55	0.92	38
B3C10	0.31	0.5	26	0.81	16
B3C20	0.31	0.5	33	0.84	27
B3C30	0.31	0.5	41	0.88	32
B3C40	0.31	0.5	52	0.92	43

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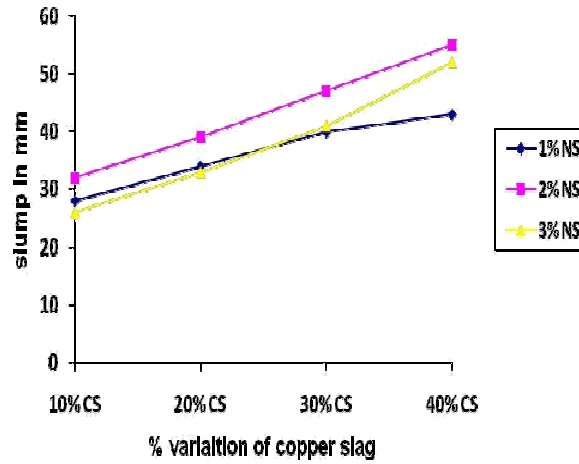


Fig .3. Slump values for various HPC samples

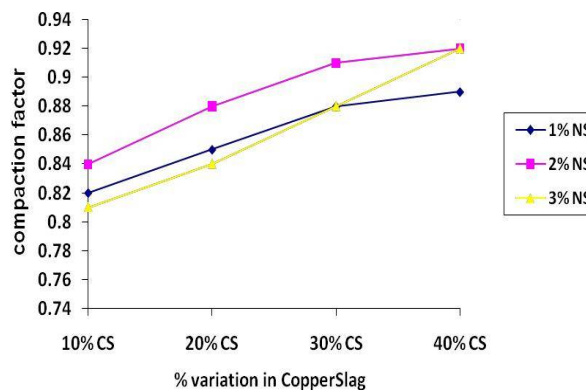


Fig .4. Compaction factor values for various HPC samples

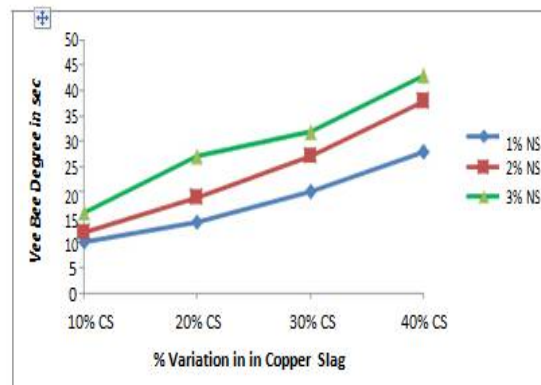


Fig.5. Vee Bee Consistometer test results for various HPC samples

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## 3.2. CUBE COMPRESSIVE STRENGTH

The cube compressive strength results at the various stages of curing are given in the table 5.2 and in the graph 5.4 to 5.10. from the graph we can understand that very early strength is achieved for all mixes when nano silica is used. The replacement of cement by nano silica is done for 1%, 2% and 3% and the maximum strength is attained at an optimum of 2% replacement of nano silica for various % replacements of Copper slag also. This Strength increment is due to the pozzolanic reaction and filler effects of NS. In the pozzolanic reaction NS reacts with Calcium Hydroxide to produce more C-S-H gel, which becomes the source of the strength increment.

Table .4 Compressive strength for various ages of curing

Specimen ID	Cube compressive strength in Mpa	
	B1C10	54.7
B1C20	54.6	70.3
B1C30	55.7	74.7
B1C40	53.6	69.4
B2C10	55.3	75.2
B2C20	56.7	76.3
B2C30	57.0	78.5
B2C40	54.3	72.1
B3C10	52.6	72.7
B3C20	53.9	73.5
B3C30	56.1	75.8
B3C40	50.7	70.1

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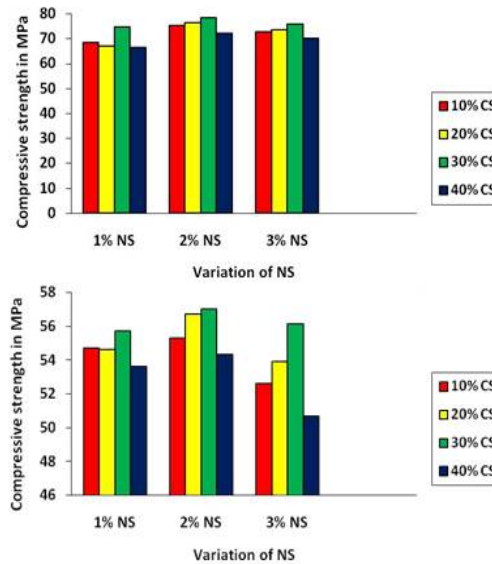


Fig.6 Compressive strength test at 7 and 28 days

Table. 5 Rate of development of Compressive Strength of Cube Specimens

Specimen ID	Strength Ratio in (%)	
	f7/f28	f28/f28
B1C10	0.80	1
B1C20	0.78	1
B1C30	0.75	1
B1C40	0.77	1
B2C10	0.74	1
B2C20	0.74	1
B2C30	0.73	1
B2C40	0.75	1
B3C10	0.72	1
B3C20	0.73	1
B3C30	0.74	1
B3C40	0.72	1



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The strength activity index at the ages of 7 and 28 for 2NS30CS are 0.73, 1.09 respectively.  $f_7$ ,  $f_{28}$  is the compressive strength at the ages of 7, 28 respectively.

### 3.3. SPLIT TENSILE STRENGTH

The Split tensile strength after 28 days for various combinations of nano silica and copper slag are given in the table. The variation of splitting tensile strength at the age of 28 days for various mixes is plotted in the form of graph as shown in fig. From the test results, the split tensile strength value is increased while increasing the % increment of NS upto 2, then it is decreased further increasing of NS. The higher compressive strength shows higher tensile strength, but the rate of tensile strength is less for HPC, that is about 0.45 (fck)/0.5. 2NSC30 is having the maximum split tensile strength when compared to other combinations.

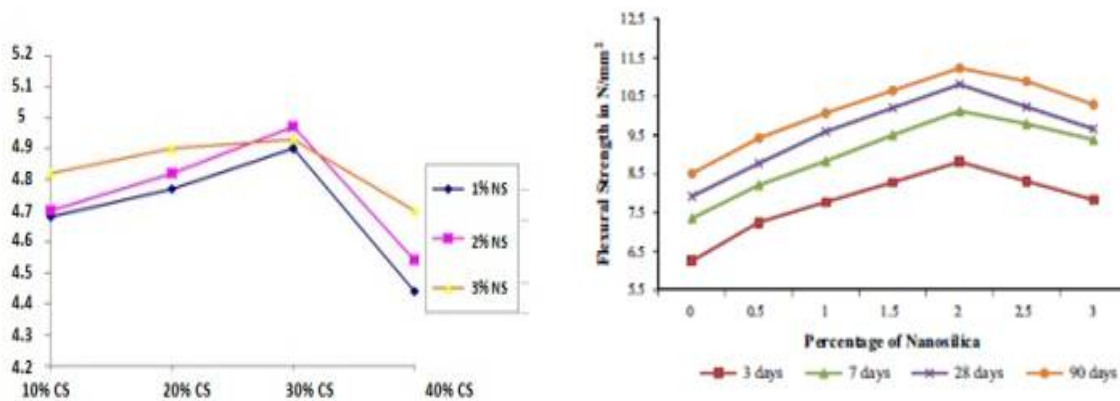


Fig.7 Split tensile test result for various HPC samples

Table 6. Various mechanical properties

Specimen ID	Split tensile strength in MPa
B1C10	4.68
B1C20	4.77
B1C30	4.90
B1C40	4.40
B2C10	4.70
B2C20	4.82
B2C30	4.97
B2C40	4.54
B3C10	4.82
B3C20	4.90
B3C30	4.93
B3C40	4.70

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### 3.4.FLEXURAL STRENGTH

The variation of flexural strength due to the addition of nanosilica at all ages. At 3 days, the mixes NS0.5, NS1, NS1.5, NS2, NS2.5 and NS3 showed an improvement in flexural strength of 7.0 MPa than control mix NS0. It was observed that the 7 days flexural strength was 7.0 MPa for the control mix NS0 and the flexural strength enhancement was 9.0 MPa for NS0.5, NS1, NS1.5, NS2, NS2.5 and NS3 mixes respectively with respect to the control mix NS0. The increase in 28 days flexural strength was 10 MPa for NS0.5, NS1, NS1.5, NS2, NS2.5 and NS3 mixes respectively than control mix NS0. The mechanical properties of copper slag concrete were improved with the increase in percentage of nanosilica in comparison to the reference concrete particularly at early ages.

### 3.5 NON-DESTRUCTIVE TEST

In the hardened concrete, the Nondestructive tests like Rebound hammer test & Ultrasonic pulse velocity test were carried out as per IS 13311 [17,18].

Rebound hammer test:

A Schmidt hammer, also known as a Swiss hammer or a rebound hammer, is a device to measure the elastic properties or strength of concrete or rock, mainly surface hardness and penetration resistance. The hammer measures the rebound of a spring-loaded mass impacting against the surface of the sample. By reference to the conversion chart, the rebound value can be used to determine the compressive strength.

Ultrasonic pulse velocity test:

Ultrasonic Pulse Velocity (UPV) testing of concrete is based on the pulse velocity method to provide information on the uniformity of concrete, cavities, cracks and defects. The test equipment must provide a means of generating a pulse, transmitting this to the concrete, receiving and amplifying the pulse and measuring and displaying the time taken.

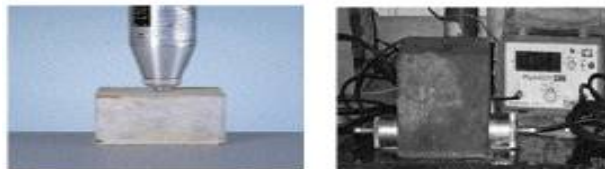


Fig.9 Compressive Strength of Cube by Rebound Hammer Test

Table .7. Average Compressive Strength of Cube by Rebound Hammer Test

Replacement of fine Aggregate (%)	7th day Compressive strength (N/mm <sup>2</sup> )	28th day Compressive strength (N/mm <sup>2</sup> )
0	9.81	10.00
20	16.19	25.75
30	21.14	30.16
40	26.49	35.64

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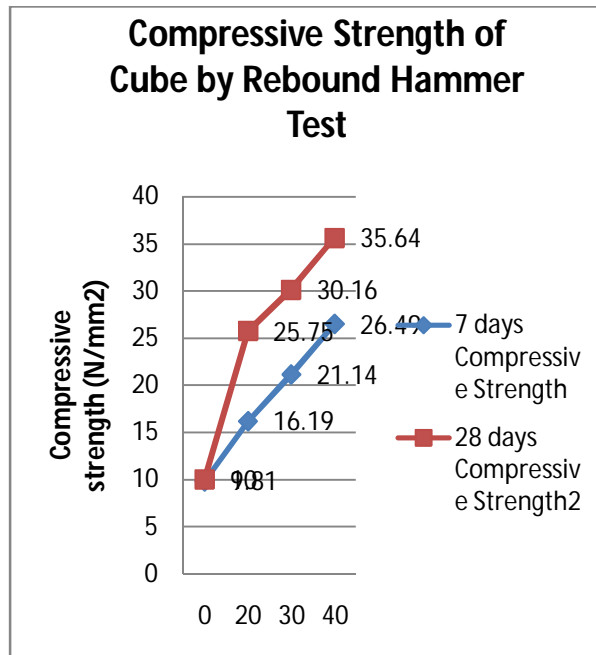


Fig.10. Compressive Strength of Cube by Rebound Hammer Test

Table 8. Ultrasonic pulse velocity test of cube.

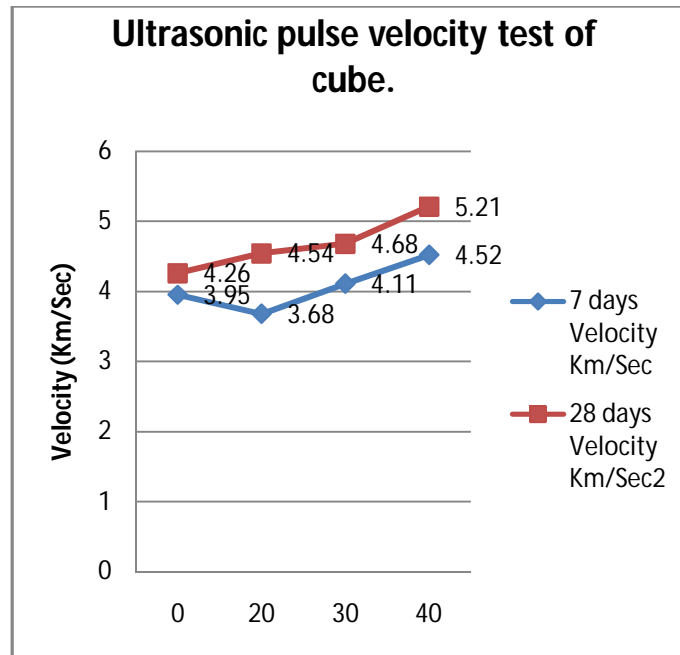
Replacement of fine Aggregate (%)	7 days		28 days	
	Velocity (Km/Sec)	Concrete Quality	Velocity (Km/Sec)	Concrete Quality
0	3.95	Good	4.26	Good
20	3.68	Good	4.54	Excellent
30	4.11	Excellent	4.68	Excellent
40	4.52	Excellent	5.21	Excellent

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**Fig.11 Ultrasonic pulse velocity test of cube.**

**Table.9. Ultrasonic pulse velocity test of cube.**

Replacement of fine Aggregate (%)	7 days		28 days	
	Velocity (Km/Sec)	Concrete Quality	Velocity (Km/Sec)	Concrete Quality
0	3.95	Good	4.26	Good
20	3.68	Good	4.54	Excellent
30	4.11	Excellent	4.68	Excellent
40	4.52	Excellent	5.21	Excellent

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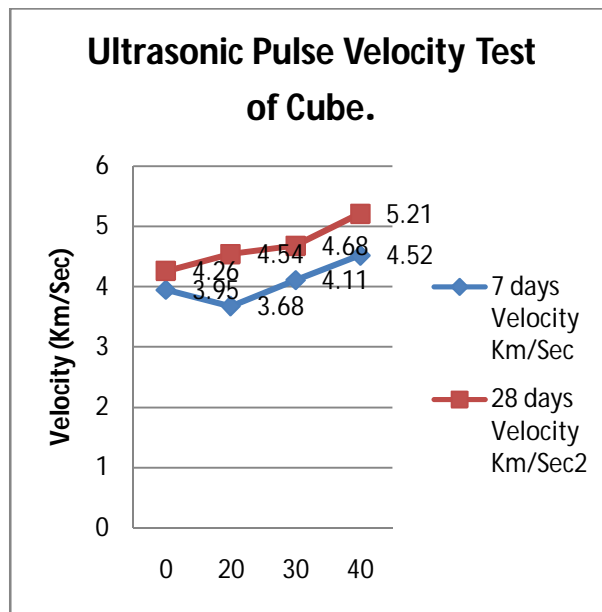


Fig.12 Ultrasonic pulse velocity test of cube.

## IV. CONCLUSION

Based on the Experimental Investigation results, the following conclusions can be made.

In workability point of view, the increase in the percentage of Nano Silica reduces the workability value at the same time increasing percentage of Copper Slag increases the workability in various HPC mixes.

The percentage increment of nano silica increases amount of SP and the usage of Copper slag reduces the dosage of superplasticizers with constant water to binder ratio.

The compressive strength achievement is very high in early age of curing for various HPC samples. This is due to pozzolanic reaction of silica nano particles which results in high production of C-S-H gel.

The compression failure pattern on concrete is only due to crushing of coarse aggregate, but not due to bond failure.

The higher value of mechanical properties suggests that the optimum percentage replacement of nano silica and copper slag is 2% and 30% respectively.

The use of NS with less w/b ratio resulted in practically impermeable concrete.

For fixed value of Nano Silica, the workability value increases while increasing the % of copper slag for various HPC samples.

For fixed value of Nano Silica with constant w/b ratio, the mechanical and durability properties are improved while increasing the % of copper slag.

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