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## Mechanical Properties of High Strength Concrete with Copper Slag as Fine Aggregate and Partially Replacing Cement with Nano Silica

M.N.V. Dayakar Reddy<sup>1</sup>, Dr.T.Chandra Sekhara Reddy<sup>2</sup>

M.Tech Student, Department of Civil Engineering, G.Pulla Reddy College of Engineering, Kurnool,  
Andhra Pradesh, India<sup>1</sup>

Professor, Department of Civil Engineering, G.Pulla Reddy College of Engineering, Kurnool, Andhra Pradesh, India<sup>2</sup>

**ABSTRACT:** During the past few years, high-strength concrete (HSC) has been increased in building structures. The use of HSC for construction, especially for buildings, bridges, has become very common in industrialized and developing countries. Now a days, the demand of natural sand is very high due to the large usage of concrete to satisfy the rapid infrastructure growth. In the present study in order to investigate the mechanical properties of high strength concrete with copper slag as a replacement of fine aggregate and partially replacing cement with nano silica. High strength concrete (M80) is designed as per ACI 211.4R-08. The work is carried out in 2 phases, in the first phase fine aggregate is replaced with Copper slag (i.e., from 0 % to 100%). In the second phase, By keeping the optimum percentage replacement (40%) of copper slag is kept constant and cement is replaced with nano silica 1% ,2%,3%. Concrete mix specimens were evaluated for compressive strength, split tensile strength, flexural strength. The test results indicate that replacement of 40% copper slag with 2% nano silica as maximum compressive strength compared to conventional concrete.

**KEYWORDS:** Copper Slag

### I. INTRODUCTION

Concrete is an important part of society's infrastructure. It is a useful construction material and innovations are constantly being made in new types and applications for it. However in recent years, the applications of high-strength concrete have increased, and high-strength concrete has now been used in many parts of the world. The growth has been possible as a result of recent developments in material technology and a demand for higher-strength concrete. Artificially manufactured aggregates are more expensive to produce, and the available source of natural aggregates may be at a considerable distance from the point of use, in which case, the cost of transporting is a disadvantage. Protecting the depleting natural sand resource and the shore line is a major concern of the day. It is essential today, to reduce excessive consumption of the natural river sand and there by prevent sand mining. It is possible by utilization of industrial by-products as well as other waste materials in the production of normal concrete and HSC. These products can be used as partial or full replacement of Aggregates. Copper slag is an industrial by-product material produced during the process of manufacturing of copper. About 2.2 tones of copper slag is generated, for every ton of copper production. Utilization of copper slag in applications such as aggregates has threefold advantages of eliminating the costs of dumping, reducing the cost of concrete, and minimizing air pollution problems.

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## II. LITERATURE REVIEW

**ByungSik Chun et al., (2005)**<sup>[1]</sup> conducted several laboratory tests and analyzed by monitoring the stress and ground settlement of clay, sand compaction pile and copper slag compaction pile. **Wei wu et al., (2010)**<sup>[2]</sup> observed that when copper slag was used to replace fine aggregate, up to 40% copper slag replacement, the strength of concrete was increases while the surface water absorption decreases. **Al-Jabri et al., (2009, 2011)**<sup>[3]</sup> observed that the water demand reduced by about 22% for 100% copper slag replacement. The strength and durability of High Strength Concrete improved with the increase in the content of copper slag of upto 50%. However, further additions of copper slag caused reduction in the strength due to increase in the free water content in the mix. **Alnuaimi (2012)**<sup>[4]</sup> results showed that the replacement of up to 40% of fine aggregate with copper slag caused no major changes in concrete strength, column failure load, or measured flexural stiffness (EI). **R R Chavan & D B Kulkarni (2013)**<sup>[5]</sup> concluded that Maximum Compressive strength of concrete increased by 55% at 40% replacement of fine aggregate by copper slag and flexural strength increased by 14 % for 40 % replacement. **S. Chithra et.al., (2016)**<sup>[6]</sup> studied the Multiple Regression Analysis (MRA) and Artificial Neural Network (ANN) models are constructed to predict the compressive strength of High Performance Concrete containing nano silica and copper slag as fine aggregate replacement respectively. **Khanzadi et al(2010)**<sup>[7]</sup> reported the influence of NS particles on the mechanical properties and durability of concrete through measurement of compressive and tensile strength, water absorption and the depth of chloride penetration. The splitting tensile strength assessments, thermal behaviour and microstructure of concrete containing different amounts of ground granulated blast furnace slag and SiO<sub>2</sub> nano particles as binder were investigated by **Nazari and Riahia(2011)**<sup>[8]</sup>. **Min-Hong Zhang, JahidulIslam(2012)**<sup>[9]</sup> has used NS to reduce setting times and increase early strength of concrete with high volumes of fly ash or slag. Based on the experimental results by using NS in pastes, mortars and concretes with about 50% of fly ash. **Hou et al(2012)**<sup>[10]</sup> showed that the pozzolanic activity of colloidal NS (instead of NS powder) was higher than that of SF and its hydration acceleration effect was also higher than SF in the early age, but this effect was comparable to that of SF in the later stage.

Based on the available literature review, Copper Slag is chosen as a replacement material for fine aggregate. In the present work, fine aggregate is replaced with Copper slag (i.e., from 0 % to 100%). optimum mechanical properties were determined. By Keeping those optimum percentage replacements constant, cement is replaced with Nano Silica there after mechanical properties were found. Thus, significance of the present work is to prove that copper slag is the better replacement for fine aggregate.

## III. MATERIALS USED

### CEMENT:-

In this work ULTRATECH cement of Ordinary Portland Cement (OPC) 53 grade was used for all concrete mixes. The various tests conducted on cement are initial and final setting time, specific gravity, fineness and compressive strength are shown in table 1.

### FLY ASH :-

The Fly Ash used in this study is of class F, obtained from RTPP, kadapa.

### FINE AGGREGATE:-

Fine Aggregate for the Experimental Program had been locally obtained and conformed to grading Zone II as per IS:383-1970. Fine Aggregate was initially sieved through 4. 75 mm sieve to remove any particles greater than 4. 75 mm after which it was washed to remove and dust. Physical properties of fine aggregates are shown Table 1.

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## COARSE AGGREGATE:-

Coarse aggregate was initially sieved through 20 mm passing sieve to remove any particles greater and were tested as per Indian Standard Specifications IS: 383–1970. Physical properties of coarse aggregates are shown in Table 1.

## COPPER SLAG:-

Copper slag is a by-product of copper extraction by smelting. During smelting, impurities become slag which floats on the molten metal. Slag that is quenched in water produces angular granules which are disposed of as waste or utilized. Copper slag is brought from Vivekananda chemicals, balanagar, Hyderabad. Physical properties of copper slag are shown in Table 1.

## STEEL FIBRES:-

Hook end steel fibers are used with aspect ratio of 67 having dia of 0.45mm and length of 30mm. It is brought from Dura flex steel fibers reinforcement procured by Kasturi composite pvt Ltd, Amaravathi, Maharashtra, India.

## SUPER PLASTICIZER:-

Structuro - 202 is differentiated from conventional super plasticisers in that it is based on a unique carboxylic ether polymer with long lateral chains. This greatly improves cement dispersion. . It allows the production of high performance concrete and/or concrete with high workability. It is brought from FOSROC construction solutions – Chennai.

## NANO-SiO<sub>2</sub> PARTICLES:-

Nano Silica is in the form of white powder. Particle size is 5 to 10nm. The Physical properties of Nano Silica Supplied by Astra chemicals, Chennai.

## WATER:-

In this project, casting and curing of specimens were done using potable water which shall be free from deleterious materials. Water plays an important role in concrete production (mix) in that it starts the reaction between the cement and the water. It helps in the hydration of the mix.

**TABLE 1 PROPERTIES OF MATERIALS**

Materials	Properties
CEMENT	Consistency - 32%, Initial setting time - 48 min Final setting time - 300 min Fineness - 4% Compressive strength - 56 N/mm <sup>2</sup> Specific gravity - 3.12
FINE AGGREGATE	Specific gravity - 2.66 Bulk density ( 1618 Kg/m <sup>3</sup> ) Fineness modulus - 3.10 Zone- II
FLYASH	Specific gravity - 2.2 Size - 5.9 μm Bulk density ( 994 Kg/m <sup>3</sup> )

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	Surface area (420 m <sup>2</sup> /kg)
COPPER SLAG	Colour - black Specific gravity - 3.2 to 3.7 Size - 0.2- 4mm Bulk density - 1870 -2100 Kg/m <sup>3</sup> Grain Shape -Granulated, Angular multi faceted
NANO SILICA	Size - 5-10 nm Specific Surface area (202 m <sup>2</sup> /gm)

### III. EXPERIMENTAL PROGRAMME

#### MIX DESIGN

In these investigations concrete mix design (M80) was designed based on ACI 211. 4R-2008. this code presents a generally applicable method for selecting mixture proportion for high strength concrete and optimizing this mixture proportion on basis of trial batches. The method is limited to high strength concrete production using conventional materials and production techniques. Mix proportioning details are given below in table 2.

#### SPECIMEN PREPARATION AND CURING

For each mix 3 cubes, 3 cylinders and 2 beams are cast. Size of cube is 100mm×100mm×100mm and cylinder size is 100mm dia × 200mm and beams of 500mm×100mm×100mm. Curing of cubes, cylinders and beam is done in normal water up to 28 days.

#### TESTING

Cubes, cylinders and beams are tested for compressive strength and split tensile strength and flexural strength at 28 days. They are tested under Compression Testing Machine (CTM) for compressive strength and split tensile strength and Universal Testing Machine (UTM) for Flexural strength.

**TABLE 2 Mix proportions**

	Cement (Kg/m <sup>3</sup> )	Fly ash (Kg/m <sup>3</sup> )	Fine Aggregate (Kg/m <sup>3</sup> )	Coarse Aggregate (Kg/m <sup>3</sup> )	Water (lit/m <sup>3</sup> )	SP (lit/m <sup>3</sup> )	Steel fibers (Kg/m <sup>3</sup> )	Copper Slag %	Copper Slag (Kg/m <sup>3</sup> )	NANO silica %	NANO silica (Kg/m <sup>3</sup> )
M0	500	124	675	1038	156	6.24	10	-	-	-	-
M1	500	124	607.5	1038	156	6.24	10	10	67.5	-	-
M2	500	124	540	1038	156	6.24	10	20	135	-	-
M3	500	124	472.5	1038	156	6.24	10	30	202.5	-	-
M4	500	124	405	1038	156	6.24	10	40	270	-	-
M5	500	124	337.5	1038	156	6.24	10	50	337.5	-	-
M6	500	124	270	1038	156	6.24	10	60	405	-	-
M7	500	124	202.5	1038	156	6.24	10	70	472.5	-	-

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M8	500	124	135	1038	156	6.24	10	80	540	-	-
M9	500	124	67.5	1038	156	6.24	10	90	607.5	-	-
M10	500	124	0	1038	156	6.24	10	100	675	-	-
M11	495	124	405	1038	156	6.24	10	40	270	1	5
M12	490	124	405	1038	156	6.24	10	40	270	2	10
M13	485	124	405	1038	156	6.24	10	40	270	3	15

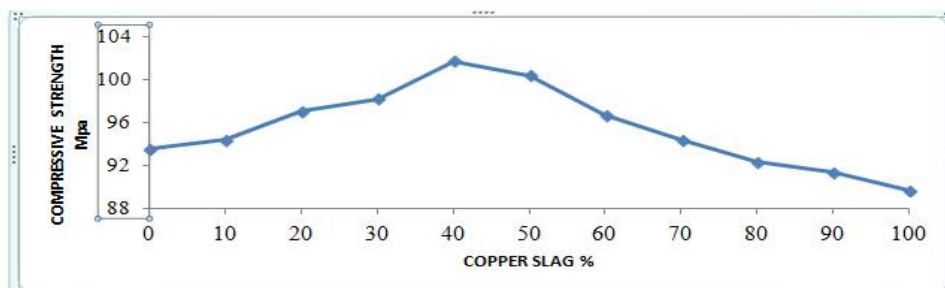
## V. RESULTS AND DISCUSSIONS

### Compressive Strength

Compressive strength of M80 concrete with fully replacement of fine aggregate by Copper Slag from 0% to 100 % and the results are shown in table 3. The maximum compressive strength of 101.66N/mm<sup>2</sup> is achieved for the concrete mix with 40% replacement of fine aggregate by copper slag which is 8.7% more than that of reference mix for 28 days curing. Figure 1 shows Variation of compressive strength for Copper slag.

**Table 3: Compressive strength of M80 concrete for different % of Copper Slag.**

Concrete mixes	%replacement fine aggregate with copper slag	Compressive strength in N/mm <sup>2</sup> at 28 days
M0	0%	93.5
M1	10%	94.33
M2	20%	97.0
M3	30%	98.16
M4	40%	101.66
M5	50%	100.33
M6	60%	96.66
M7	70%	94.33
M8	80%	93.33
M9	90%	91.33
M10	100%	89.66



**Fig 1:- Variation of compressive strength of M80 concrete for different % of Copper Slag**

The compressive strength of M80 Grade concrete were study with 1, 2, 3 % of Nano SiO<sub>2</sub> and 40% copper slag are shown in table 4. Maximum compressive strength is 105N/mm<sup>2</sup> is obtained for concrete mix with 2% replacement of cement by Nano SiO<sub>2</sub> which is 3.28% more than that of concrete mix without Nano SiO<sub>2</sub> for 28 days curing. Figure 2 shows Variation of compressive strength for nano silica.

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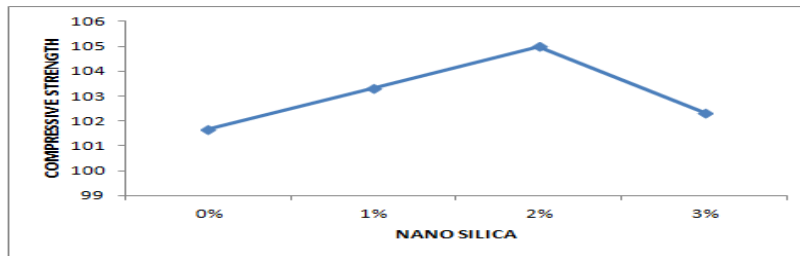
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**Table 4: Compressive strength of HSC(M80) with 40% Copper Slag for different % of Nano SiO<sub>2</sub>.**

Concrete mixes	% replacement fine aggregate with copper slag	Nano silica %	Compressive strength in N/mm <sup>2</sup> at 28 days
M4	40%	0%	101.66
M11	40%	1%	103.33
M12	40%	2%	105
M13	40%	3%	102.33



**Fig:2: Variations of compressive strength of HSC (M80) with 40% Copper Slag for different % of Nano SiO<sub>2</sub>.**

### Split Tensile strength:-

Split Tensile strength of M80 concrete with fully replacement of fine aggregate by Copper Slag from 0% to 100 % and the results are shown in table 5. The maximum split tensile strength of 4.615 N/mm<sup>2</sup> is achieved for the concrete mix 40% replacement of fine aggregate by copper slag which is 20.8 % more than that of reference mix for 28 days curing. Figure 3 show Variation of Split Tensile strength for Copper slag.

**Table 5: Split Tensile strength of M80 concrete for different % of Copper Slag.**

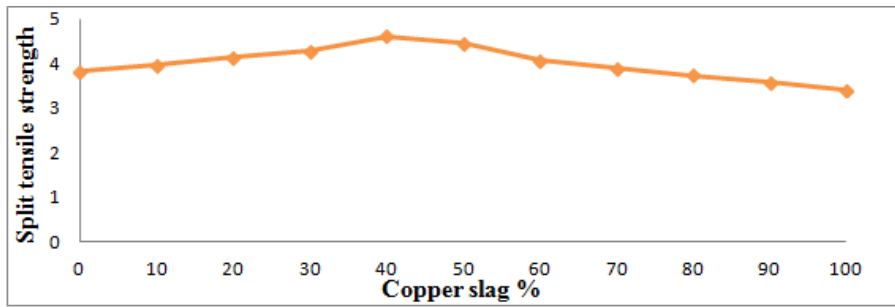
Concrete mixes	% replacement fine aggregate with copper slag	Split Tensile strength in N/mm <sup>2</sup> at 28 days
M0	0%	3.82
M1	10%	3.978
M2	20%	4.138
M3	30%	4.297
M4	40%	4.615
M5	50%	4.456
M6	60%	4.058
M7	70%	3.90
M8	80%	3.74
M9	90%	3.58
M10	100%	3.42

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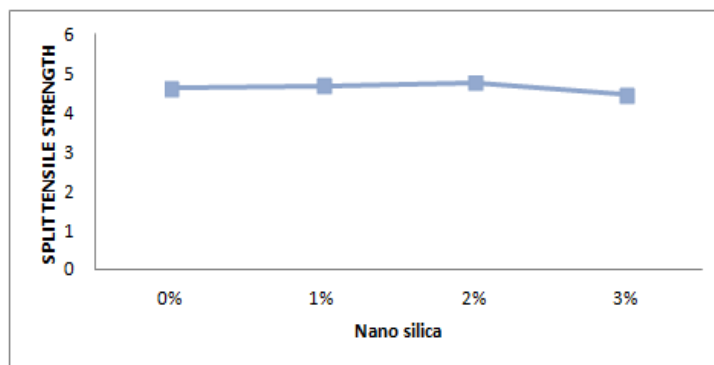


**Fig3:-Variations of split tensile strength of HSC (M80) for different % of Copper Slag.**

Split Tensile strength of M80 Grade concrete were study with 1, 2, 3 % of Nano SiO<sub>2</sub> and 40% copper slag are shown in table 6. Maximum split tensile strength is 4.774 N/mm<sup>2</sup> is obtained for concrete mix with 2% replacement of cement with Nano SiO<sub>2</sub> which is 3.44 % more than that of concrete mix without SiO<sub>2</sub> for 28 days curing. Figure 4 show Variation of Split Tensile strength for Nano silica.

**Table 6: Split Tensile strength of (M80) concrete with 40% Copper Slag for different % of Nano SiO<sub>2</sub>.**

Concrete mixes	% replacement fine aggregate with copper slag	Nano silica %	Split Tensile strength in N/mm <sup>2</sup> at 28 days
M4	40%	0%	4.615
M11	40%	1%	4.695
M12	40%	2%	4.774
M13	40%	3%	4.456



**Fig 4 :-Variations of split tensile strength for (M80) concrete with 40% Copper Slag for different % of Nano SiO<sub>2</sub>.**

**Flexural strength:-**

Modulus of rupture strength of M80 concrete with fully replacement of fine aggregate by copper slag and the results are shown in table 7. The maximum modulus of rupture strength of 6.04 N/mm<sup>2</sup> is achieved for the concrete mix 40% replacement of fine aggregate by copper slag which is 17 % more than that of reference mix for 28 days curing. Figure 5 show Variation of Flexural strength for Copper slag.



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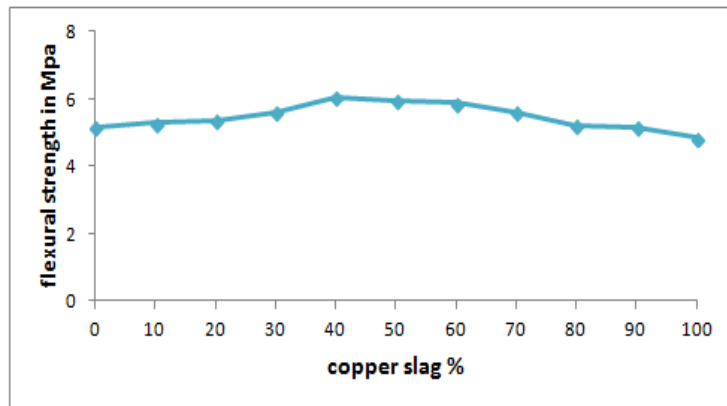
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**Table 7: Flexural strength (M80) concrete for different % of Copper Slag.**

Concrete mixes	%replacement fine aggregate with copper slag	Flexural Tensile strength in N/mm <sup>2</sup> at 28 days
M0	0%	5.16
M1	10%	5.28
M2	20%	5.36
M3	30%	5.6
M4	40%	6.04
M5	50%	5.96
M6	60%	5.88
M7	70%	5.60
M8	80%	5.22
M9	90%	5.16
M10	100%	4.84



**Fig 5:-Variations of flexural strength of (M80) concrete for different % of Copper Slag.**

Modulus of rupture strength of M80 Grade concrete were study with 1, 2, 3 % of Nano SiO<sub>2</sub> and 40% copper slag are shown in table 8. Maximum modulus of rupture strength is 6.36 N/mm<sup>2</sup> is obtained for concrete mix with 2% replacement of cement by Nano SiO<sub>2</sub> which is 5.29 % more than that of concrete mix without Nano SiO<sub>2</sub> for 28 days curing. Figure 6 show Variation of Flexural strength for nano SiO<sub>2</sub>.



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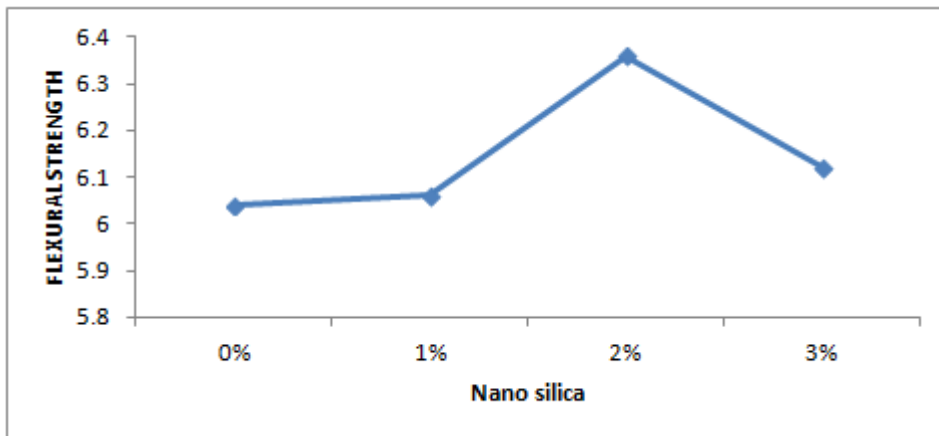
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**Table 8: Flexural strength of (M80) concrete with 40% Copper Slag for different % of Nano SiO<sub>2</sub>.**

Concrete mixes	% replacement fine aggregate with copper slag	Nano silica %	Flexural strength in N/mm <sup>2</sup> at 28 days
M4	40%	0%	6.04
M11	40%	1%	6.06
M12	40%	2%	6.36
M13	40%	3%	6.12



**Fig 6 :- Variations of Flexural strength for (M80) concrete with 40% Copper Slag for different % of Nano SiO<sub>2</sub>.**

## VI. CONCLUSIONS

1. The maximum compressive strength of 101.66 N/mm<sup>2</sup> is achieved for 40% replacement of fine aggregate by Copper slag which is 8.57% more than that of reference mix for 28 days curing.
2. Maximum compressive strength is 105 N/mm<sup>2</sup> is obtained for concrete mix with 40% Copper Slag and 2% replacement of cement by Nano SiO<sub>2</sub> which is 3.28% more than that of concrete mix without Nano SiO<sub>2</sub> for 28 days curing.
3. The maximum split tensile strength of 4.615 N/mm<sup>2</sup> is achieved for 40% replacement of fine aggregate by Copper Slag which is 20.8% more than that of concrete mix without Copper slag mix for 28 days curing.
4. Maximum split tensile strength is 4.774 N/mm<sup>2</sup> is obtained for concrete mix with 40% Copper Slag and 2% replacement of cement by NanoSiO<sub>2</sub> which is 3.44% more than that of concrete mix without Nano SiO<sub>2</sub> for 28 days curing.
5. The maximum modulus of rupture strength of 6.04 N/mm<sup>2</sup> is achieved for 40% replacement of fine aggregate by Copper Slag which is 17% more than that of reference mix for 28 days curing.

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6. Maximum modulus of rupture strength is  $6.36 \text{ N/mm}^2$  is obtained for concrete mix with 40% Copper Slag and 2% replacement of cement by  $\text{NanoSiO}_2$  which is 5.29% more than that of concrete mix without  $\text{NanoSiO}_2$  for 28 days curing.

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