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# An Experimental Investigation on Strength Behaviour of Concrete by Partial Replacement of Fine Aggregate with Copper Slag and Cement with Nano-Silica Liquid and Polypropylene Fiber

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***Abstract:*** ***This is the era of revolution it can be more revolutionzed by Eco friendly material like Copper Slag, Polyorpropylene Fiber and Nano-Silica Liquid. Concrete is one of the widely used building material across the world. The usage of sand in construction industry leads to the excessive mining, causing depletion of natural resources. Copper Slag waste is most usually made from the copper industry, whereas Silica Fume is a by-product from many manufactures. Chuck out of both copper slag waste and Nano –Silica Liquid is one of the major environmental problems worldwide today. Hence the reuse of waste material leads to better sustainability to the enviroment. This research paper deals with study of the Strength properties of concrete by partial replacement of fine aggregate with copper slag and cement with Nano-silica Liquid and Polypropylene Fiber in it. In the present Experimental Investigation, is carried out for M40 grade of concrete, fine aggregate (River Sand) was partially replaced with Copper Slag (40%) and cement was partially replaced with Nano-silica Liquid and Polypropylene Fiber from 5% to 15% at an interval of 5%. This research work gives a detailed study on Compressive strength, split tensile strength as well as flexural strength at age of 28 days. The research shows that the strength properties of concrete were improved having copper slag as a partial replacement of Sand (up to 40%) and Nano-silica Liquid(10%) and Polypropylene Fiber as a partial replacement of cement (up to 1.0%).***

***Keywords: Copper slag, Nano-Silica Liquid, Polypropylene Fiber, Fine aggregate, Compressive Strength, Split Tensile Strength, Flexure Strength.***

## I. INTRODUCTION

Due to rapid Urbanization infrastructure projects are increased at a very swift rate. Which leads to the production of cement at tremendous rate. A huge amount of energy is consumes in the production of cement, that releases the magnanimous amount of $CO_2$ as a chief sources of air pollution. A huge amount of solid waste is produced in forms of copper slag, silica fume and recron fiber which can be use sustainable building material . Concrete is matrix of aggregates , sand, cement and water. Several studies are made that shows, increase in strength parameters of concrete by partial replacing sand with copper slag . Copper Slag, which is a by-product (having Silica (SiO2) as a major chemical composition) obtained during matte smelting and refining process of copper production, is abundantly available and even possesses a low risk to health and the environment and could be considered as an alternative to river sand. Utilizing these waste slags in Concrete also helps in resolving the dumping or disposal problem of the industrial waste which is a major concern today.Where as polypropylene fiber provides a secondary reinforcement for the concrete.

## II. LITERATURE REVIEW

Ghutke & BhandariExamine the Influence of silica fume in concrete. Results indicated that the silica fume is a better replacement of cement. The rate of strength gain in silica fume concrete is high. Workability of concrete decreases as increase with % of silica fume. The optimum value of compressive strength can be achieved in 10% replacement of silica fume. As strength of 15% replacement of cement by silica fume is more than normal concrete. The optimum silica fume replacement percentage is varying

from 10 % to 15 % replacement level. [1]

Sharma & SeemaExamined the issue of partial replacement of cement with silica fume on compressive strength of concrete. M20 grade of concrete with a W/C ratio as 0.5 and percentage replacement was 0%, 10%, 20%. The optimum compressive strength is obtained at 20% cement replacement by a Silica Fume at all age strata (i.e. 24 hours, 7& 28 days). The 28 days' compressive strength at 20% replacement was found to be 32.29 MPa with a slump value of 21 mm[2]

Leema Rose & Suganya examined the Performance of Copper Slag on Strength and Durability Properties as Partial Replacement of Fine Aggregate in Concrete. The main aim of this study is to find the strength and durability properties of concrete in which fine aggregate replaced with Copper slag partially by 10%, 20%, 30%, 40%. They concluded that the addition of copper slag in concrete increases the density of the concrete. The results of compressive tests show that the strength of the concrete increases with respect to the percentage of copper slag added by weight of fine aggregate up to 30% of replacement of copper slag strength was found to be

45.42 N/mm2 for a design mix 1: 1.4: 2.6 keeping w/c ratio as 0.4[3] Srinivasu, Kranti, Nagasai & Saikumar studied on compressive strength properties and effects of copper slag as partial replacement of fine aggregate in concrete. The Two different types of concrete grades M30 & M40 were used with different percentage of copper slag replacement from 0 to 100 percentage. The percentage replacement of sand was 0%, 10%, 20%, 30%, 40%, 50%, 60%, 80% & 100%. The concrete was tested for 7 days & 28days compressive strength after casting the mounds. Increased compressive strengths for the above grade of concretes Were observed. For M30 grade concrete, the highest compressive strength was achieved at 7days by 50% replacement of copper slag is39.105Mpa and the maximum compressive strength was achieved at 28days by 10% replacement of copper slag and which was found about 44.66MPa, compared with nominal mix (29.87N/mm2 and 41.65N/mm2) and for M40 grade concrete, the maximum compressive strength was achieved at 7days by 20% replacement of copper slag is 44.44MPa and the highest compressive strength was achieved at 28days by 50% replacement of copper slag and which was found about 53.105MPa, compared with nominal mix (32.33N/mm2 and 47.11N/mm2).[4]

Zerdi conducted an Experimental Investigation on Properties of Concrete by Replacement Copper Slag for Fine Aggregate. The fine aggregates were replaced with percentages 0% (for the control mix), 20%, 40%, and 60% of Copper Slag by weight. Tests were performed for properties of fresh concrete and Hardened Concrete. Compressive strength was determined at 3, 7,14 and 28 days. Properties like workability and density were increased with the use of copper slag in concrete. Improvement in the strength properties of plain concrete by the inclusion of up to 40% Copper slag as replacement of fine aggregate was observed as 25.58 N/mm2at 28 days for M20 concrete. [5]

Singh &Bath in their paper studied the use of copper slag as fine aggregate - a case study. Dependence on natural aggregates as the main source of aggregate in concrete can be replaced by artificially manufactured aggregates or artificial aggregates generated from industrial wastes and has provided an alternative for the construction industry. The results indicate that the use of copper slag in concrete increases the flexural strength of about 17% with that of control mixture. It is recommended that up to 40% of copper slag can be used as replacement of fine aggregates. Maximum flexural strength (6.67 N/mm2) was observed for 40% replacement after that flexural strength trend decrease for further replacement. [6]

Patil, Patil & Veshmawala observed the Performance of Copper Slag as Sand Replacement in Concrete.M30 concrete was used and various tests like compressive, flexural, split tensile strength were conducted for different percentages of copper slag and sand from 0 to 100%. The result showed that workability increases with increase in percentage of copper slag. Maximum Compressive strength of concrete increased by 34 % at 20% replacement of fine aggregate with copper slag, and up to 80% replacement of copper slag, concrete gain more strength than normal concrete strength. The flexural strength of concrete found to be increased by 14% with 30% replacement of copper slag. [7]

Arivalagan carried an Experimental Study on the Flexural Behavior of Reinforced Concrete Beams as Replacement of Copper Slag as Fine Aggregate. The test results of concrete were obtained by adding copper slag to sand in various percentages ranging from 0%, 20%. 40% 60%, 80% and 100%. All specimens were cured for 28 days before compression strength test, splitting tensile test and flexural strength. The highest compressive strength obtained was 35.11MPa (for 40% replacement) and the corresponding strength for control mix was 30MPa [8].

Velumani & Maheswari studied on Mechanical and Durability Properties of RC Beams Using Copper Slag as Fine Aggregate in Concrete. Copper slag has physical properties similar to the fine aggregate, so it can be used as a replacement for fine aggregate in concrete. Copper slag has lower absorption and higher strength properties than fine aggregate. Replacement of copper slag increases the self-weight of concrete specimens to the maximum of 15% to 20%. [9] BMadhavi, Pavan Kumar &Jothilingam

studied on Effect of Copper Slag on the Mechanical Strengths of Concrete. Experimental investigations are carried out by replacing the sand with copper slag in proportions of 10%, 20%, 30%, 40%, 50%, 60% and 100% keeping all other ingredients constant. It was seen that the optimum content of copper slag is 40% beyond which the strength starts decreasing. [10 Nataraja, Chandan & Rajeeth studied on concrete mix design using copper slag as fine aggregate. This paper presents the experimental results of an on-going project to produce concrete with copper slag as a fine aggregate. The effect of replacing fine aggregate with copper slag on the compressive, flexural and split tensile strength of concrete are studied in this work. It was seen that for design mix (1:1.66:3.76) with w/c = 0.45 and 0 to 60% replacement 7- days compressive strength (MPa)was found to be 36.00(equivalent volume) 37.26(equivalent weight) for 100% replacement of copper slag [11]

Shia, Meyer & Behnood studied on Utilization of copper slag in cement and concrete. The cement, mortar and concrete containing different forms of copper slag have good performance in compressive strength with ordinary Portland cement having normal and even higher strength. [12] Abhinav Shyam, Abdullah Anwar & Syed Aqeel Ahmad studied on Effect of Copper Slag as Partial Replacement of Fine Aggregate in Concrete. Partial replacement of fine aggregate with copper slag reveals that there is a significant change in the strength properties of concrete such as compressive strength, flexural strength, split tensile strength. They observed the improvement in the strength of concrete in terms of Compressive Strength, Flexural Strength and Tensile Strength on partial replacement of fine aggregate with copper slag.[13] Hanumesh, Varun & Harish Observes the Mechanical Properties of Concrete Incorporating Silica Fume as Partial Replacement of Cement. The primary purpose of this study is to examine the mechanical properties of M20 grade control concrete and silica fume concrete with different percentages (5, 10, 15 and 20%) of silica fume as a partial replacement of cement. The outcome showed that the compressive strength of concrete is increased by the use of silica fume up to 10% replacement of cement. From 10% there is a reduction in compressive strength and the split tensile strength of concrete is increased by the use of silica fume up to 10% replacement of cement. From 10% there is a decrease in split tensile strength. The optimal percentage of replacement of cement by silica fume is 10% for M20 grade of concrete. [15]

## III. EXPERIMENT DETAILS

### A. *Material used and their Properties*

*1) Cement:* Ordinary Portland Cement of 43 grades manufactured by Shree Ultratech Cement was used throughout the Experimental investigation. The quality of the cement was confirmed as per IS 4031-1988 and all the quality tests were conducted conforming to the specifications of 12269-1987.Results of the various test are Tabulated in Table 1

Table 1: Physical Properties of Ordinary Portland cement:

| Characteristics | Observed Value |
|---|---|
| Normal Consistency | 30% |
| Initial Setting Time | 45 minutes |
| Final Setting Time | 615 minutes |
| Specific Gravity | 3.15 |
| Compressive Strength at 28 days | 43.5 Mpa |

### B. *Fine Aggregate*

The Fine Aggregate used was locally available coarse Sand. The test procedure as per IS 383: 1970 was carried out to determine the properties of Fine aggregate. The Results of the various test are tabulated in Table 2

Table 2: Physical Properties of Fine Aggregate:

| Characteristics | Observed Value |
|---|---|
| Grade Zone | III |
| Fineness Modulus | 2.26 |
| Specific Gravity | 2.62 |
| Silt Content | 1.67% |
| Water Absorption | 1.2(%) |

### C. *Coarse Aggregate*

The Coarse Aggregate used was locally available. The test procedure as per IS 383: 1970 was carried in order to determine the properties of Coarse aggregate. The Results of the various test are tabulated in Table **3**

Table 3: Physical Properties of Coarse Aggregate:

| Characteristics | Observed Value |
|---|---|
| Fineness modulus | 6.916 |
| Specific Gravity | 2.72 |
| Water Absorption | 0.5% |
| Bulk Density | 1590Kg/$m^3$ |

*D. Nano-Silica Liquid*

Nano-$SiO_2$ has been found to improve concrete workability and strength, to increase resistance to water penetration, and to help control the leaching of calcium, which is closely associated with various types of concrete degradation. Nano-$SiO_2$ was found to be more efficient in enhancing strength than silica fume. The raw material of polypropylene is derived from monomeric $C_3H_6$ which is purely hydrocarbon.

Table: 4- Properties of Nano-Silica Liquid

| S. No. | Specification | Values |
|---|---|---|
| 1- | Specific Gravity | 2.20 |
| 2- | Bulk Density | 40 |
| 3- | Moisture (%) | <1.5 |
| 4- | Loss on ignition | <1.5 |
| 5- | Surface Area($m^2$/g) | 200 |
| 7- | $P^H$ value | 3.8 – 4.3 |

*E. Polypropylene Fiber*

Polypropylene Fiber is 100% synthetic fiber.It is formed by 85% of polypropylene It is a bi-product of petroleum. Polypropylene fibers use in this research of 12 mm long and 18 micrometer in diameter size and Specific gravity is 0.91.

Table:5- Properties of Polypropylene Fiber

| S. No. | Specification | Values |
|---|---|---|
| 1- | Tenacity(gm/den) | 3.5 to 5.5 |
| 2- | Bulk Density(g/cc) | 0.91 |
| 3- | Melting Point($^0$C) | 170 |
| 4- | Moisture regain(%) | 0% |
| 5- | Elongation at break(%) | 10 - 45 |
| 6- | Softening Point($^0$C) | 140 |
| 7- | Thermal Conductivity | 6.0 |

*F. Copper Slag*

Copper slag used in this study was brought from Taj Abrasive Industries. Physical and Chemical Properties of copper slag Used in the Study Are Tabulated in Table 6 and 7.

Table 6: Physical Properties of Copper Slag

| Physical properties | Copper slag |
|---|---|
| Particle shape | Multifaceted |
| Appearance | Black & glassy |
| Type Air | Cooled |
| Specific gravity | 3.51 |
| Bulk density at $25^0$ C (Ton/$m^3$) | 1.8 - 2.2 |
| Hardness | 5 – 7 Mohs |
| pH | 6.5 |
| Conductivity at $25^0$ | Nil |
| Moisture Content | < 0.1% |

Table 7: Chemical Properties of Copper Slag

| Chemical component | % of Chemical component |
|---|---|
| $SiO_2$ | 33-35 % |
| $Fe_2O_3$ | 40-44% |
| $Al_2O_3$ | 4-6% |
| CaO | 0.8-1.5% |
| MgO | 1-2% |

*G. Chemical Admixture*

Chemical Admixtures (CICO PLAST SUPER-HS @1.5%) are materials in the form of fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes. Properties of CICO PLAST SUPER-HS are Tabulated in Table 8

Table 8: Properties of admixture

| Characteristics | CICO PLAST SUPER-HS |
|---|---|
| Specific Gravity | 1.14 |

*H. Mix Design*

As per the Code IS: 10262 -2009, the mix design was done for M40 grade mix and the amount of materials was calculated. Table 9 gives the quantities required for M40 grade of concrete Mix. The appraisal of Copper Slag as a replacement of fine aggregate and Nano-silica Liquid and Polypropylene Fiber as a replacement of Cement begins with the concrete testing.

The study is conducted to analyze the compressive strength, split tensile Strength and Flexural Strength of concrete when the base materials, i.e. Fine Aggregate is replaced with Copper Slag and Cement is replaced Nano-silica Liquid and Polypropylene Fiber respectively. Firstly, the copper slag replacement was made at proportions 0%, 10%, 20%, 30%, 40%, and 50% by weight of M-40 grade concrete. Samples were tested with the average strength values reported in this Research paper. The maximum mean value of the strength of a certain definite replacement proportion of fine aggregate with copper slag was noted.

Now, the copper slag replacement is kept at the constant proportion (proportion attaining maximum average value of strength) and Nano-silica Liquid replacement was made at proportions 5%, 10% and 15%, by weight and Polypropylene Fiber kept constant 1% by volume of M-40 grade concrete. Again, samples were tested with the average strength values reported in this paper.

All the test samples were teested and results were analyzed after curing 28 days. The result obtained from the partial replacement of fine aggregate with copper slag and partial replacement of cement with Nano-Silica Liquid with Polypropylene Fiber is compared to conventional concrete.

Table 9: Mix design and proportion of M40 grade concrete.

| Grade | Cement ($Kg/m^3$) | F. A ($kg/m^3$) | C. A ($kg/m^3$) | Water ($Kg/m^3$) | W/C Ratio | Admixture ($kg/m^3$) | Mix Proportion |
|---|---|---|---|---|---|---|---|
| M40 | 431.17 | 625.2 | 1121.05 | 172.46 | 0.4 | 6.46 | 1:1.45:2.6 |

*I. Mixes*

In this study, various mixes were prepared by adding Copper Slag in different volume fraction (0%, 10%, 20%, 30%, 40% and 50%). Table-10 gives the quantity required for various mixes.

Table 10: Concrete mix details.

| % Replacement | Cement (Kg) | Fine Aggregate (kg) | Copper slag (Kg) | Coarse Aggregate (Kg) | Water (W/C =0.4) (kg) | Admixture (gm) |
|---|---|---|---|---|---|---|
| 0 | 23.76 | 34.45 | 0 | 61.78 | 9.5 | 356 |
| 10 | 23.76 | 31 | 3.45 | 61.78 | 9.5 | 356 |
| 20 | 23.76 | 27.56 | 6.89 | 61.78 | 9.5 | 356 |
| 30 | 23.76 | 24.12 | 10.33 | 61.78 | 9.5 | 356 |
| 40 | 23.76 | 20.67 | 13.78 | 61.78 | 9.5 | 356 |
| 50 | 23.76 | 17.225 | 17.225 | 61.78 | 9.5 | 356 |

Table 11: Partial Replacement of Cement by Silica Fume with copper slag fixed as 40% Water (w/c = 0.4 kg) = 9.5 Admixture (gm) = 356

| S.No | % replacement of Nano-Silica Liquid | Cement (kg) | Nano-Silica Liquid (%) | Polypropylene Fiber(%) | Copper slag (kg) | Coarse aggregate (kg) | Fine aggregate (kg) |
|---|---|---|---|---|---|---|---|
| 1 | 5 | 22.57 | 5 | 1.0 | 13.78 | 61.78 | 20.67 |
| 2 | 10 | 21.38 | 10 | 1.0 | 13.78 | 61.78 | 20.67 |
| 3 | 15 | 20.19 | 15 | 1.0 | 13.78 | 61.78 | 20.67 |

*J. Discussion Of Result*

1) *Compressive Strength Test Results:* The results in Table-12 show the compressive strength of M40 grade concrete with varying Copper slag at 28 days. The percentage change in strength with respect to normal concrete at 28 days is graphically plotted.

Table 12: Compressive Strength of concrete at 28 days

| % Replacement | Compressive Strength in $N/mm^2$ | % Increase in Strength |
|---|---|---|
| 0 | 48.90 | 0 |
| 10 | 49.95 | 2.14 |
| 20 | 50.01 | 2.26 |
| 30 | 50.35 | 2.96 |
| 40 | 51.05 | 4.4 |
| 50 | 49.85 | 1.94 |

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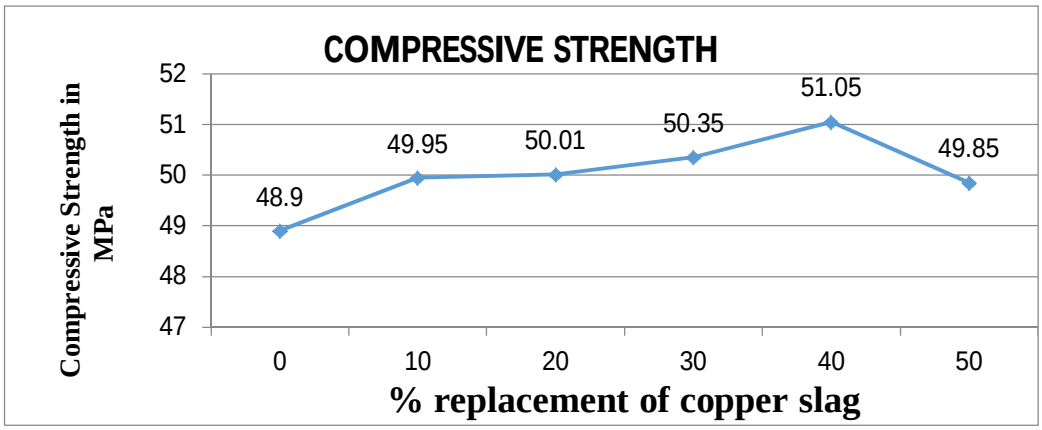


Figure 1: Compressive Strength of Concrete with Partial Replacement of fine aggregate by copper slag

Table 13: Compressive Strength of concrete at 28 days Partial Replacement of Cement, with Copper Slag Proportion, i.e. 40%)

| % Replacement of Nano-Silica Liquid with Polypropylene fiber(1%) | Compressive Strength ($N/mm^2$) |
|---|---|
| 5 | 53.45 |
| 10 | 56.74 |
| 15 | 51.20 |

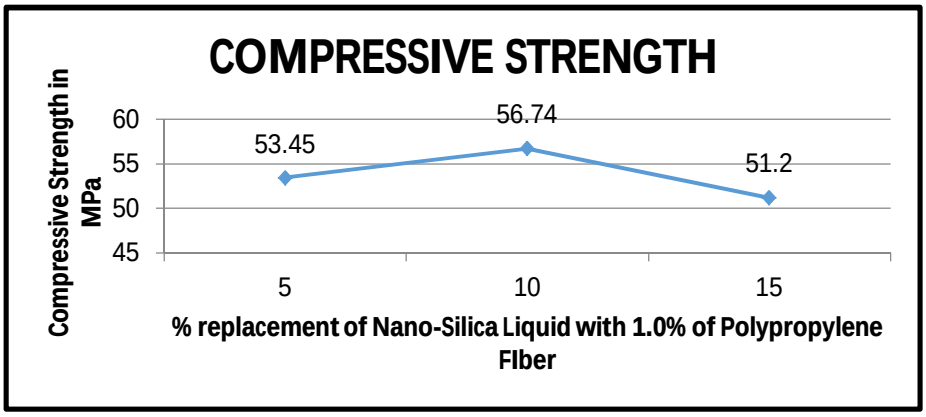


Figure 2: Compressive Strength of Concrete with Partial Replacement of Cement by Silica Fume

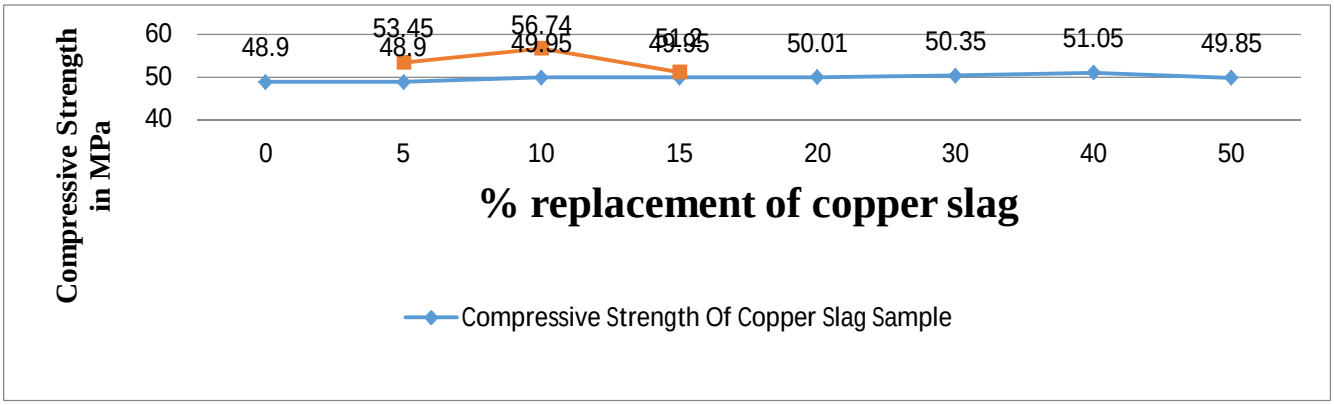


Figure 3: Comparison of Compressive Strength

2) *Flexural Strength Test Results:* The results in table-14 show the flexural strength of M40 grade concrete with copper slag fixed and table-16 shows the flexural strength with Copper slag fixed as 40% and varying ano-Silica Liquid and Polypropylene fiber (at 28 days Along with Flexural strength, the percentage change in Flexural strength with respect to normal concrete is plotted.

Table 16: Flexural Strength of concrete at 28 days

| % Replacement | Flexural Strength | % Increase in Strength |
|---|---|---|
| 0 | 6.85 | 0 |
| 10 | 7.12 | 3.94 |
| 20 | 7.25 | 5.8 |
| 30 | 7.45 | 8.76 |
| 40 | 7.79 | 13.7 |
| 50 | 7.13 | 4.08 |

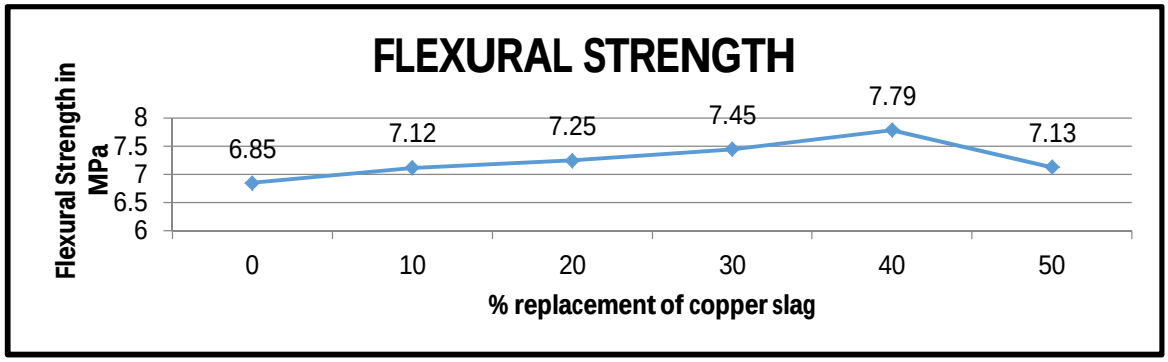


Figure 7: Flexural Strength of Concrete with Partial Replacement of Fine aggregate by Copper Slag

Table 15: Flexural Strength of Concrete at 28 days (Partial Replacement of Cement, with Copper Slag Proportion, i.e. 40%)

| % Replacement of Nano- Silica Liquid with Polypropylene fiber | Flexural Strength ($N/mm^2$) |
|---|---|
| 5 | 7.89 |
| 10 | 8.23 |
| 15 | 7.52 |

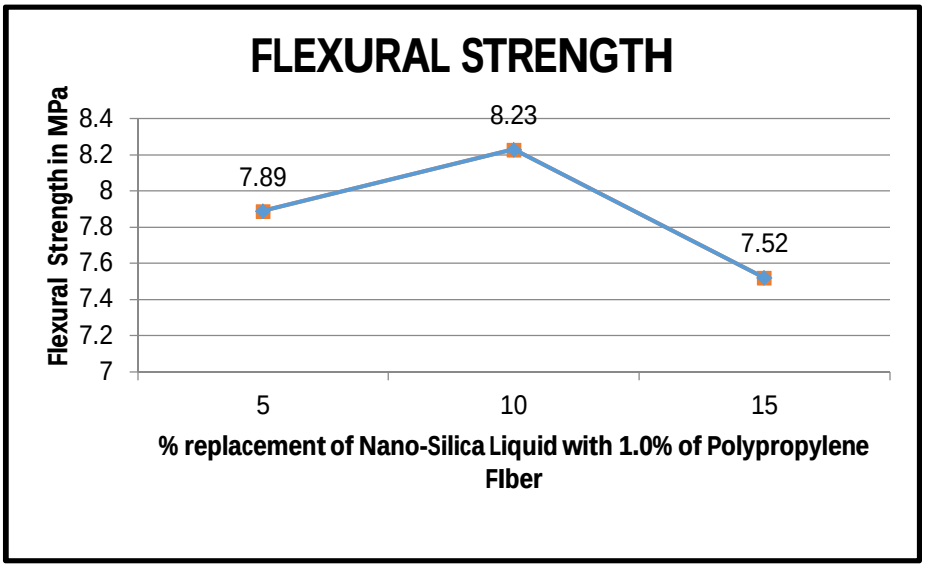


Figure 8: Flexural Strength of Concrete with Partial Replacement of cement by Nano-Silica with Polypropylene Fiber

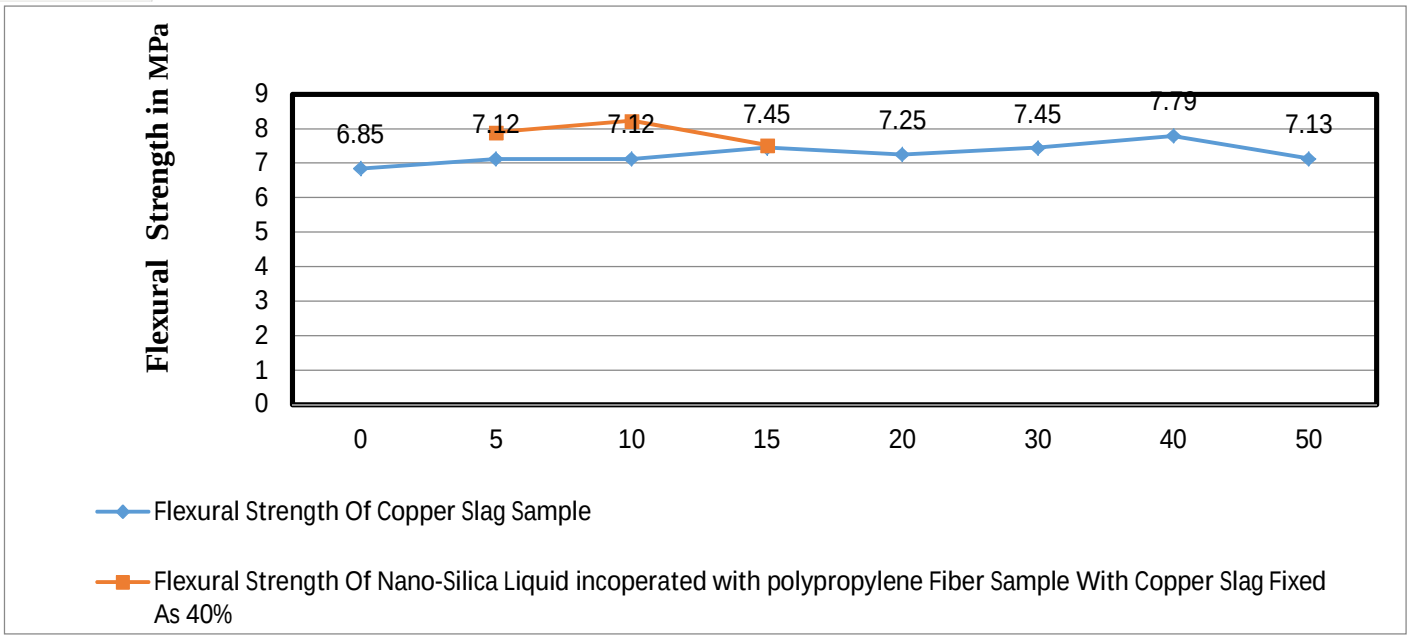


Figure 9 : Comparison of Flexural Strength

## IV. CONCLUSION

From the experimental investigations conducted, the following are the conclusions drawn.

*A.* Copper slag concrete showed substantial increase in strength when used with in acceptable quantities.

*B.* Copper Slag has a potential to provide as an alternative to fine aggregate up to 40% and helps in maintaining the environmental as well as economical balance.

*C.* Copper slag is a one of the best material for replacement of fine aggregate in concrete.

*D.* The maximum strength was achieved by 40 % replacement of fine aggregate with copper slag. Further increase of copper slag reduces the effectiveness.

*E.* Nano-Silica Liquid and polypropylene fiber in concrete showed a acceptable gain in strength when used within permissible quantities.

*F.* The utmost intensity was achieved for 10 % replacement of Cement with Nano-Silica Liquid and polypropylene fiber.

*G.* Compressive Strength was increased by 4.4% when compared to the Nominal mix for 40% replacement of fine aggregate with Copper Slag

*H.* Split tensile Strength was increased by 14.52% when Compared to Nominal mix for 40% replacement of Copper Slag

*I.* Flexural Strength was increased by 13.7% when Compared to Nominal mix for 40% Replacement of Copper Slag

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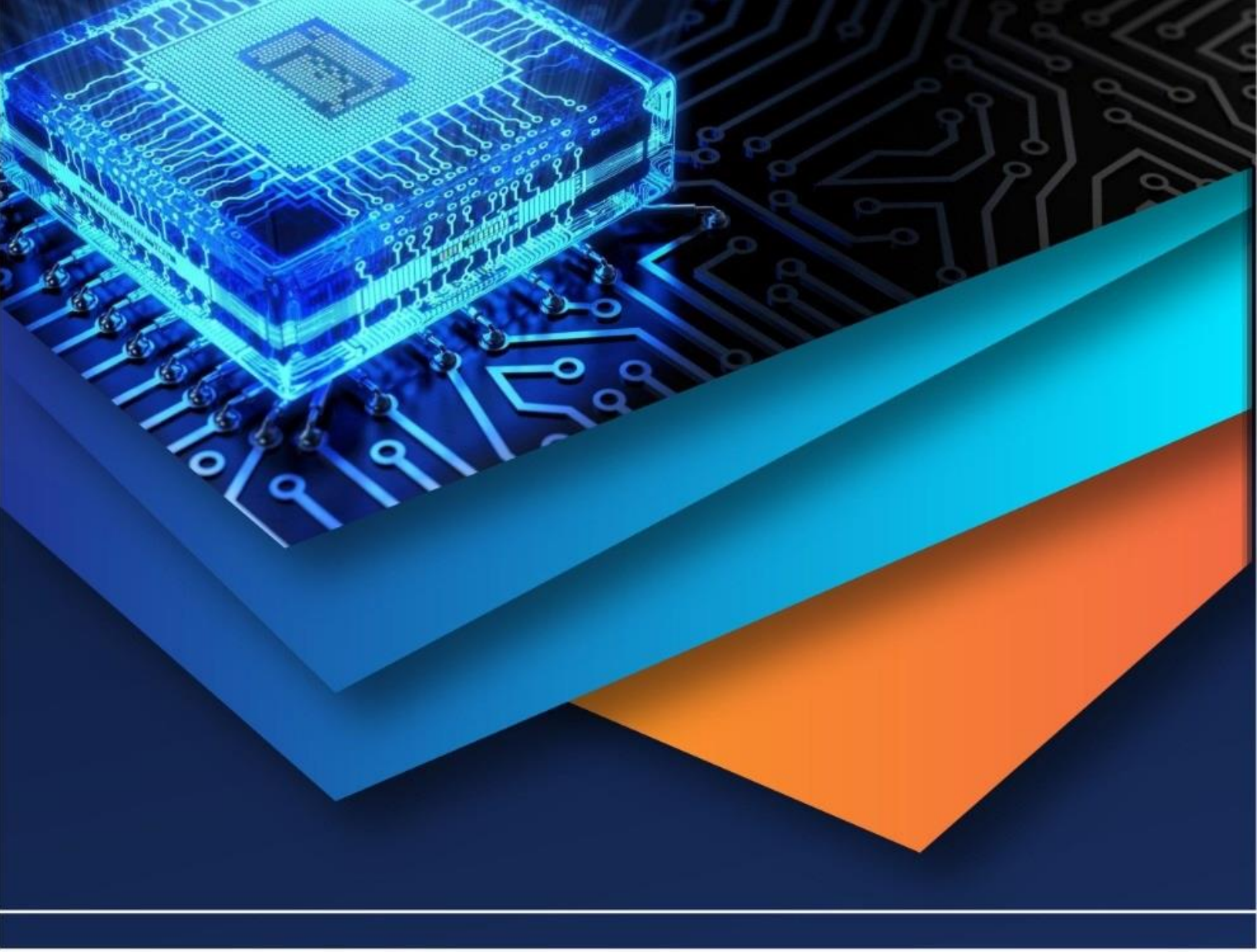

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