EXPERIMENTAL INVESTIGATIONS ON PARTIAL REPLACEMENT OF CEMENT WITH NANO SILICA AND FINE AGGREGATE WITH COPPER SLAG IN CONCRETE PAVEMENTS

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ABSTRACT:- In developing country like India every decade, the population growth has been increasing. Hence, the Indian government fulfills its basic needs like power and employment and at the same time, industrialization and urbanization are the requirement to lead their life. Though these are the necessity of the society, they are unavoidable. During the industrialization, large quantity of industrial wastes has been generated. The wastes are generated from different industrial processes. They are of complex characteristics and different chemical compositions, also affect health and environment. Hence, safe management and the disposal of waste are very important to maintain the sustainable environment. Only the concrete industries are responsible for utilizing these waste materials because, large quantity of natural resources is consumed in concrete and also some positive properties are also present in the industrial by- product.

Copper industries in India take up about 3% of the entire world market of copper. Indian Copper companies - Sterlite Industries, Hindalco, and Hindustan have contributed to the production of major quantities of copper. Copper slag is produced during pyrometallurgical production of copper from copper ores, which contain substantial amount of materials like iron, alumina, calcium oxide, silica etc. For every tonne of metal production, about 2.2 tonnes of slag are generated. At present, about 33 million tonnes of Copper Slag (CS) are generated annually worldwide and among that, India contributes 6 to 6.5 million tonnes. Very small quantity of copper is present in the copper slag and also separation of copper from slag is a very complex process. Air-cooled copper slag has number of favourable mechanical properties to be used as aggregate, including excellent soundness characteristics, good abrasion resistance and good stability than the granulated copper slag. Copper slag is used in the production of cement, mortar and concrete as raw materials for clinker, partial replacement for cement, coarse and fine aggregate, respectively.

In India, construction sector is under tremendous pressure to explore alternative to the basic construction material to meet the growing demand of infrastructure demands because of increasing scarcity of river sand and natural aggregates across the country. In some states of our country, sand mining in rivers has been banned, owing to its disastrous impact ecology. And also conservation of natural resources is very essential in any modern development due to industrialization, and the production of waste materials is also increased.

These waste materials must be utilized, due to the presence of positive properties similar to the aggregate. In this work, detailed investigation has been carried out on the industrial by-products such as CS and FA to find their suitability as suitable alternative materials for cement and fine aggregate. The strength of the concrete alone is not the prime importance because the concrete structures are constructed in hostile environment such as acidity, alkalinity and heavy industrial areas etc. Hence, every year large amount of money is spent to maintain the concrete structures. As a result, this research paves way to the meticulous investigation on the mechanical, and durability properties of nano silica and copper slag in concrete.

M40 grade Concrete mix is designed as per IS: 10262-2009 .Twenty four mixes are prepared for each grade of concrete by replacing cement with nano silica from 0%, 10%, 20% and 30%, with 10% increment by mass and the fine aggregate is replaced by copper slag from 0% to100% with 20% increment by mass. Coarse aggregate and water cement ratios are maintained constant.

Slump and compaction factor tests are carried out for each mix. By using Destructive Testing (DT), compressive strength, splitting tensile strength and flexural strength tests are conducted. Compressive strength test has been conducted on 288 cubes of size 150mm x150mm x 150mm at 3,7,14, 28, 56 and 90 days curing periods using compression testing machine with the capacity of 2000kN. Use of copper slag can save the natural resources like the sand which is very critical now a day as in most of the metros, artificial sand has been utilized for production of concrete. This utilization can serve not only to prevent the negative environmental impact but also to preserve and protect nature. Characterization of various sources of copper slag has been provided.

Keywords: copper Slag, Nano Silica, Rigid Pavement

1. INTRODUCTION

In India, construction sector is under tremendous pressure to explore alternatives to the construction material, as the demand of construction materials like river sand and natural aggregates has been increasing greatly across the country. In some states of our country, sand mining in rivers has been banned, owing to its disastrous impact ecology. Conservation of natural resources is very essential in any modern development. In addition, due to the scarcity of natural resources, the waste materials must be properly utilized to make the environment eco-friendly. Each waste material, with some specific properties is associated to natural materials and also the requirement of natural materials for concrete making is increased, due to the development of infrastructure in developing countries. Preparation of concrete consumes great amount of natural materials and large amount of energy. As a result, concrete industry is should take responsibility for reusing the waste materials in concrete. The utilization of by- products in concrete as replacement for fine aggregate and coarse aggregate or cement not only reduces the environmental pollution but also reduces the cost of concrete making. The use of industrial solid waste to produce concrete is environmentally friendly because, it reduces the consumption of natural resources. It also prevents the environmental pollution, globalwarming effect, health problems, scarcity of land for dumping the waste materials and the power consumption.

2. MATERIALS USED:

NanoSilica:- Nano silica can be amorphous or crystalline, porous or non-porous (dense), anhydrous or hydroxylated, regardless of the natural or synthetic nature. It is commercially available in the market in colloidal form as a stable dispersion of solid silica particles. The nominal size of nano silica particles is 10 nm, 20 nm, 30 nm and 40 nm. Chemically, nano silica is composed mainly of pure silica (99%).

Table 1 Physical characteristics of Nano silica

S. No.	Property	Value
1.	Average Particle size (nm)	20
2.	Density (g/cm^3)	2.4
3.	Molar Mass (g/mol)	59.90
4.	Melting Point (°C)	1610
5.	Boiling Point (°C)	2225
6.	Specific gravity	1.31
7.	Specific Surface (m^2/g)	140

COPPERSLAG:- Copper slag from Vizag Chemicals Pvt Ltd from Vishakhapatnam Andhra Pradesh is utilized and its properties are given in Table 2

Table 2 Physical properties of copper slag

Specification	Results
Specific gravity	3.52
Fineness modulus	3.53
Bulk Density kg/m3	1750
Void ratio	0.8
Water absorption %	0.13

Coarse Aggregate: Crushed blue granite stones of maximum size of 20mm are used as coarse aggregate, which has satisfied the IS383-1970 standard.

Table 3 Physical properties of coarse aggregate

Specification	Results
Specific gravity	2.75
Fineness modulus	7.6
Bulk Density kg/m3	1380
Void ratio	0.95
Grading Zone	Max size 31.5mm
Water absorption %	0.45

Cement:- Ordinary Portland cement (43 Grade) is used for the entire research, and it confirms the current specifications as described in IS8112 (part1):2013. The properties of the cement are given in the Table 4. The following tests have been conducted in accordance with IS codes.

Table 4 Physical properties of cement - OPC 43 grade

Physical Properties	Test result
Specific gravity	3.15
Normal consistency (%)	36%
Initial setting time (minutes)	90
Final setting time (minutes)	420

FineAggregate:- Locally available natural sand of zone II with 4.75mm maximum size is used as fine aggregate, which has satisfied the IS383-1970 standard. The fine aggregate is first sieved through 4.75 mm sieve to remove the particles greater than 4.75mm. The results are given in Table 3.3.

Table 3.3 Physical properties of fine aggregate

Specification	Results
Type	River Sand
Specific Gravity	2.51
Fineness modulus	2.79
Grading zone	Zone II
Water Absorption	1.08%

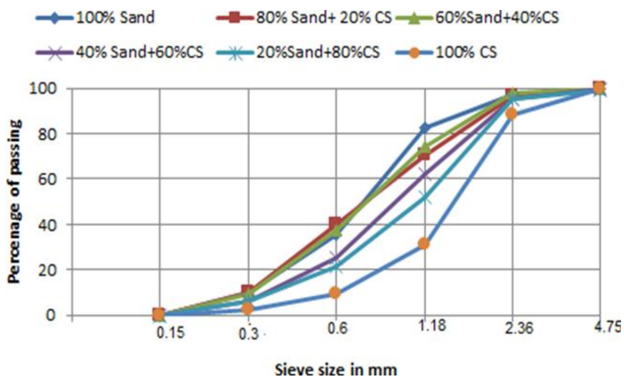

Figure 1 Grading curves

From these results, it is clear that copper slag has higher fineness modulus and bulk density than the fine aggregate. Copper slag is substituted for fine aggregate from 0 to 100% at a 20% increment. As per the particle size distribution of the fineness modulus for fine aggregates are 2.8, 2.82, 2.83, 3.11,3.25 and 3.53, respectively for 0%, 20% 40% 60% 80% and 100% copper slag replacement for fine aggregates. From these results, it is understood that the copper slag is coarser than the natural sand and surface area is less. Hence water requirement is decreases, when the quantity of copper slag is increased in concrete. The introduction of copper slag shifts the gradation curve towards right because the fineness modulus values are increased.

Mix Composition for M40Grade

Twenty four mix proportions are prepared with, cement is partially replaced by NS from 0% to 10% with increment by mass and the fine aggregate is replaced by CS from 0% to 100% with 20% increment by mass. Coarse aggregate and water cement ratio are kept constant as 1293 kg/m3 and 0.4. Totally twenty four concrete mix proportions are prepared and mix proportions of M40 grade.

CASTING OF SPECIMENS:- All the specimens are casted as per mix proportions given in Table 3.10. The required materials are mixed properly and ensure uniformity and water is added with constant water cement ratio of 0.4. Then they are mixed properly. The concrete is mixed using laboratory tilting drum mixer machine. All the moulds are properly oiled before casting the specimens. Before casting the specimen, fresh concrete property is carried out and then, the concrete is placed in standard size cast ion moulds with three equal layers. Compaction has been carried out by vibrating table. After 24-hours the specimens are demoulded, transferred to curing tank and tested at required age.

3. EXPERIMENTAL TESTS & RESULTS:-

3.1 TEST RESULTS OF FINESS OF CEMENT

S.NO	Experimental values	SAMPLE-1	SAMPLE-2
1	Sample taken in gm.	100	100
2	Passing through is:90mic. sieve	98.60	99.20
3	Retainedon is:90mic. sieve	1.40	0.80
4	Fineness (%)	1.40	0.80
5	Average	1.10	

3.2 CONSISTANCY OF CEMENT (IS:4031 P-4-1988)

S.NO	Experimental values	SAM-1	SAM-2	SAM-3
1	Wt. Of Sample In gm.	350	350	350
2	Water Added In ml	101.5	103.25	105
3	Reading In Mm Of Apparatus	15	11	6
4	water % for consistancy	29	29.5	30
5	selected consistancy	30.00%		

3.3 SETTING TIME OF CEMENT

S.NO	Experimental values	Results
1	starting time in hrs	10.40 AM
2	initial setting time in hrs	12.55 PM
3	final setting time in hrs.	02.25 PM

3.4 Workability:- Increasing the quantity of nano silica in concrete, increases fines volume. Hence, requirement of water demand is increased but water demand is decreased for CS quantity increased in concrete and as a result, the bleeding of concrete is reduced.

3.5 Density of the Concrete:- In this study, density of concrete is higher than the normal density of concrete and less than the high density of concrete. Low density concrete is also undesirable, due to its relatively poor performance under reversed cyclic loading and so, this concrete may be suitable for earthquake prone areas.

3.6 Compressive Strength:- At the early age, nano silica exhibits strengthening cementing value but at later ages, liberated surplus lime resulting from hydration of cement reacts with NS and contributes considerable strength to the concrete. Target mean strength of M40 grade of concrete as per the mix design is 48.25N/mm2. At 28 days curing period optimum compressive strength has been reached 57.04N/mm2 at NS 5CS40. Most of the mix proportions satisfied the target mean strength.

3.7 Splitting Tensile and Flexural Strength

The results of the splitting tensile strength (150mm diameter x 300mm height) and flexural strength (100mm x 100mm x 500mm prisms) at 28 days are obtained in this study according to the procedures described in IS516- 1959. From the experimental results, it is illustrated that the splitting tensile and the flexural strength behave in similar manner. The optimum strength is reached, when the concrete with 10%NS -60% CS replacement for cement and 40% CS replacement for fine aggregate. After that, strength profiles decline. The mix with up to 40% CS increases the tensile strength of concrete. The reason for increased tensile strength may be a strong interface bond between the CS and NS paste. Irregular surfaces of CS aggregate particles are filled with hydration products. As a result, they provide better bond strength and hence, the tensile strength is increased.

3.8 Durability Properties Of concrete:- After 90 days of water curing, the specimens are tested to determine the durability properties such as Saturated Water Absorption(SWA), Porosity, Sorptivity, Co-efficient of permeability, Abrasion(28 days), Carbonation(150 days) Corrosion measurement of rebar by linear polarization resistivity (25 cycles of wetting and drying in 3.5% NaCl), Alkalinity (90 days curing period) tests are conducted and micro structural studies such as SEM and EDAX are conducted on the sample for the optimum compressive strength obtained at 28 and 90 days curing period.

3.9 Non Destructive Testing(NDT):- Non Destructive testing methods such as Ultrasonic Pulse Velocity (UPV) and Rebound Hammer tests are performed on the reinforced cement concrete beams before conducting flexural strength test. Uniformity of the concrete measured by the ultra sound measurements is performed through 20 paths (every150mm spacing) along the length of the beam by direct transmission method. The results are represented in the Table 5.10. From these results, it is clear that the uniformity of the concrete is varied in every place from 3.09 km/s to 4.79 km/s. Velocity of the concrete 4.79 km/s means that the quality of concrete is excellent and 3.09 km/s means the quality of the concrete is doubtful based on the IS 13311(Part 1):1992 . In each rebound hammer test, 20 readings are taken and the hammer is vertically applied in all the readings. The surface hardness of the concrete is displayed in terms of compressive strength N/mm2and they are 30.8, 32, 26.2,30 and 31, respectively for NS0CS0, NS0CS40, NS3CS40, NS5CS80 and NS10CS80.

3.10 Ultrasonic Pulse Velocity Test

The velocity of the propagation of ultrasound pulse is measured by direct transmission method using UX4600 ultrasound device. From these results, it is clear that UPV values of all the mix proportions vary from 4.0 km/s to 4.7 km/s. In this experiment, velocity obtained is higher. This indicates that the quality of the concrete in terms of density, homogeneity and uniformity is good. Based on the IS13311 (part 1) 1992, velocities of all concrete mixtures are indicated 'excellent and good'.

3.11Rebound HammerTest

In RH method, compressive strength is directly measured by DIGI Schmidt (2000) Rebound Hammer (Proceq). RH strengths of all the mix proportions achieve the required strength of M30 grade of concrete at 28 days and also the results are comparable with control concrete. But, the strengths are largely scattered compared to the compressive strength obtained by destructive testing results. The estimation of the strength of concrete by rebound hammer method cannot be held to be very accurate and the probable accuracy of prediction of concrete strength in a structure is ±25 percent as reported by IS13311 (part 2) 1992. This is because the RH results are affected by number of factors like surface condition, moisture content, age of concrete etc. RH values are also indicative of compressive strength of concrete to a limited depth from the surface. If the concrete has internal micro cracking, flaws or heterogeneity across the cross-section, RH strength will not indicate the same. But, UPV values indicate that the concrete has uniform homogeneity, less amount of cracks, voids and other imperfections. From these results, it is concluded that both the NDT and the DT techniques results are favorable for concrete with industrial wastes such as NS and CS. Compressive strengths obtained by destructive testing results are compared with UPV and RH.

3.12 Ultrasonic Pulse Velocity Test:-

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4. CONCLUSIONS

Gradation of aggregates

- As per the particle size distribution the fineness modulus value of CS is higher than the fine aggregates.
- Copper slag has less surface area and hence, water requirement is decreased to attain the sufficient workability

Workability

- Slump and compaction factor values are increased, when the quantity of CS and NS is increased in concrete.
- Based on the gradation test, 100% natural sand is finer than the CS and as a result, the requirement of water is increased to attain medium workability of concrete, due to increased surface area.
- Water absorption of copper slag is 0.13% compared whereas the water absorption of sand is 1.08%. Therefore, the workability of concrete increase significantly with the increase of copper slag content in concrete mixture.
- Based on the SEM images, both CS and NS have spherical particles. So, the workability of concrete is increased, due to ball bearing effects of NS and CS.

Density of Concrete

- The density of concrete is increased, when the quantity of copper slag is increased in concrete. It happens because of high ferrous content present in copper slag. But, the density of concrete is slightly decreased, due to low specific gravity of nano silica.
- Based on the density of concrete, it is concluded that, higher density concrete is suitable for reversal loading condition.

Compressive strength

- In concrete with NS alone, the initial rate of gain of compressive strength has been decreased, due to slow pozzolanic action, but the strength is developed at later ages .
- From the compressive strength test results, it can be seen that, when the curing periods increased, higher strength is obtained for 57.04N/mm2 at NS 5CS40 concrete with replacement of 5%nano silica and 40% copper slag, respectively.
- In 28 days curing period, compressive strength of the all the mix proportions are yielded higher than the target mean strength of M40 grade of concrete
- Here we found that nano silica helps to improve to attain early strength and durability of the concrete.

Splitting tensile and flexural strength

- Based on the tensile strength of concrete NS10CS60 mixture is suitable for pavement, runways and air field constructions.
- Higher compressive strength reached at 28 days of 6.1 N/mm2 at NS 5CS40concrete shows higher tensile strength. Use of pozzalanic materials increases the tensile strength of concrete.

Non Destructive Testing (NDT)

- UPV varies from 4.0 km/s to 4.7 km/s for all the mixtures. The results reveal that, the concrete has uniform homogeneity, with fewer amounts of cracks, voids and other imperfections.
- RH strengths of all mix proportions achieve required strength for M40 grade of concrete at 28 days. It is clear that the RH reflects only the concrete surface properties.

Based on the above points, it has been concluded that the blended concrete has good potential and functionally appropriate material and commercial use of blended concrete can be initiated in the production of concrete in general and for pavement concrete in particular. Also, concrete mix with blended concrete not only leads to many technical advantages but at the same time it is benefitted in protecting and preserving natural resources. It can be used in urban as well as in rural areas for rigid pavement as nowadays in metro cities artificial sand is utilized for production of concrete.

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