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ASSESMENT OF MECHANICAL PROPERITIES OF CONCRETE STRENGTH USING COPPER SLAG

K.NAGENDRA REDDY[1], K.CHANDRAKALA[2], P.MADAN MOHAN REDDY[3]
[1,2,3]Assistant Professor, Dept of Civil Engineering, AITK, Kadapa, AP, India.

Abstract- Concrete is widely used in all types of infrastructural applications because it offers considerable strength at a relatively low cost. The popularity of the concrete is due to the fact, that from the common ingredients, it is possible to tailor the properties of concrete to meet the demands of any particular situation. Concrete is an Artificial Stone resulting from hardening of rationally chosen mixture of cement, fine aggregate, coarse aggregate and water. The advances in concrete technology have paved the way to make the best use of locally available materials by judicious mix proportioning to produce concrete satisfying the performance requirements. This concrete is the most widely used construction material in the world, with about two Billion tons of utilization worldwide during each year. Natural Sand available from River beds, pits etc., was readily used as fine aggregate in all types concrete mixes. Due to rapid urbanization, there is a huge demand / requirement of natural sand (as fine aggregate) for the construction industry, thereby natural resources of sand was getting depleted day by day, have brought pressures to reduce consumption through the use of supplementary materials. The sustainable development in the construction industry involves the use of non- conventional and innovative materials and recycling of waste materials in order to compensate the lack of natural resources and to find alternative ways for conserving the environment. Copper slag (by-product material produced during the process of manufacturing Copper), is one of the waste material which could have a promising future in construction industry as partial substitute of fine aggregate in concrete mixes. Hence an attempt has made to study the Compressive Strength, Split tensile Strength and Flexural Strength of concrete using different proportions of Copper Slag in concrete mixes to finalize the optimum % of mix which can yield better strength properties. The results presented in this thesis, form part of an investigation on the use of Copper slag as partial substitute / replacement for natural sand as fine aggregate in concrete.

I. INTRODUCTION

In the present scenario, as a result of continuous growth in population, rapid industrialization and the accompanying technologies involving waste disposal, the rate of discharge of pollutants into the atmosphere, copper slag is one of the industrial waste which comes out from blast furnace during metal extraction process. Copper slag is produced as a by-product of metallurgical operations in reverberatory furnaces. Originally imported from Japan, copper slag was used as an abrasive material for removing rust and marine deposits from ships through sandblasting. After repetitive recycling and reuse, the copper slag lost its original abrasive property and with no good use thereafter and was disposed in landfills. Copper slag is totally inert material and its physical properties are similar to natural sand. A laboratory study was carried out in the Institute to investigate the potential of using copper slag as a partial replacement of sand in cement concrete.

The use of copper slag in cement and concrete provides potential environmental as well as economic benefits for all related industries, particularly in areas where a considerable amount of 56copper slag is produced. Due to rapid urbanization, there is a huge requirement of fine aggregate i.e., natural sand for the production of concrete in construction industry, which led to the continuous mining of natural sand from river beds. These results in lot of environmental issues like lowering of water table, erosion of nearby lands, increased pollution due to reduced natural filtration capacity which is detrimental for aqua-culture. Hence Supreme Court imposed certain regulations and restrictions on the mining/ quarrying of sand from river bed locations. In many countries, there is a scarcity of natural aggregate that is suitable for construction, whereas in other countries the consumption of aggregate has increased in recent years, due to increases in the construction Industry. In order to reduce depletion of natural aggregate due to construction, artificially manufactured aggregate and some industrial waste materials can be used as alternatives. Thus our project is to utilize the copper slag by the replacement for fine aggregate for maintaining economy and increasing the strength of concrete. By this project we can also solve the problem of disposal of this type of industrial waste. Different types of slag according to the property can be utilized in different purposes.

The demand for natural sand is quite high in developing countries since the available sand is not able to meet the demands of construction sector, because natural sand takes millions of years to form and it is not replenish able. Due to continuous dragging of the sand from River beds reduces the water head, leads to less percolation of rain water in to the ground. This leads to lower

ground water level, which results in scarcity of drinking water. Hence there is an urgent need to identify a suitable substitute for natural sand, which should be eco-friendly and inexpensive. On the other hand, large quantities of slag produced as a by-product of metallurgical operations, resulting in environmental concerns with its disposal. Hence, there is an increased need to explore the possibility of utilization of Industrial waste materials in making concrete. This will lead to sustainable concrete design and greener environment.

II. LITERATURE REVIEW

Washington Almeida Mouraet al.(4th Brazilian MRS Meeting), 2007. This paper presents the results of a study on the use of Copper Slag as Puzzalonic Supplementary Cementing material for use in concrete. Initially the chemical and mineralogical characteristics of the Copper Slag were determined. After this, concrete batches were made with copper slag additions of 20% (relative to the cement weight) and set properties were investigated, i.e., specific gravity, compressive strength, splitting-tensile, absorption and absorption rate by capillary suction and carbonation. The results pointed out that there is a potential for the use of copper slag as a supplementary cementing material to concrete production. The concrete batches with copper slag addition presented greater mechanical and durability performance. The following conclusions were drawn from this study. The addition of copper slag to concrete results in an increase on the concrete's axial compressive and splitting tensile strengths. It was observed that a decrease in the absorption rate by capillary suction, absorption and carbonation depth in the copper slag concrete and its durability also improved.

Hwang C.L. and Laiw J.S., reported that the amount of bleeding of mortar made with Copper slag is comparatively less than that using natural sand. They evaluated the Compressive Strength development of mortars and concrete containing fine Copper slag aggregate with different water- cement ratios. The results indicated that the mortars containing the large amounts of Copper slag sand has lower early Strengths of Concrete with 20- 80 % substitution of Copper slag was found to be higher than that of Control concrete specimens (with 0% of C.S.).

Al-Jabri KS et al. studied the effect of Copper slag substitutions as fine sand on the strength and durability of High Strength Concrete. Concrete mixtures with different proportions of Copper slag (ranging from 0% to 100% replacement) were prepared and Concrete samples were tested to assess the properties of the produced concrete at different curing ages. The results showed that the workability increased substantially with the increase of Copper slag content in the concrete mixture due to the low water absorption and glassy surface of Copper slag compared with natural sand.

D.Brindha et al. reported the Compressive Strength and the Split Tensile Strength test have indicated that the Strength of Concrete increases with respect to the % of Slag added by weight of fine aggregate up to 40% of additions and 15% of cement. Water absorption of Concrete specimens (with up to 40% of Copper slag) is 22% lower than the controlled specimens and lesser permeability of Slag admixture Concrete.Moreover, the addition of Copper slag for the replacement of natural sand shows higher resistance against Sulphate attack but slightly low resistance to the Sulfuric acid (acid resistance test).

R. R. Chavan& D.B. kulkarni (2013) conducted experimental investigations to study the effect of using copper slag as are placement of fine aggregate on the strength properties and concluded that Maximum Compressive strength increased by 55% at 40% replacement of fine aggregate by copper slag and flexural strength increased by 14% for 40% replacement.

Khalifa et al, reported that the use of Copper slag as sand substitution improves strength and durability characteristics of High Strength Concrete at same workability and produces Concrete that meets Strength and durability Design requirements.

Hwang and Laiw reported that the amount of bleeding of mortar made with Copper slag is comparatively less than that using natural sand. They evaluated the Compressive Strength development of mortars and concrete containing fine Copper slag aggregate with Different water-cements ratios. The results indicated that the mortars containing the large amounts of Copper slag sand has lower early Strengths at water-cement ratio of 0.48. The Strengths of Concrete with 20-80 % substitution of Copper slag was found to be higher than that of Control concrete specimens (with 0% of C.S.).

III. DATA COLLECTION

The program was designed to describe the selection of materials, types of tests to be conducted to evaluate their properties, to prepare Design mix, to furnish casting, curing and testing procedures adopted in order to compare the mechanical properties of Concrete i.e., Compressive Strength, Splitting Tensile Strength and Flexural Strength with different percentages of Copper slag used as fine aggregate, in blending with natural sand.

A. SELECTION OF MATERIALS:

Cement: The Cement selected for this experimental work is the Ordinary Portland Cement of 53-Grade (Ultra-Tech Brand) conforming to IS: 12269-1987. This brand of cement is most widely used in the construction industry in India. The Physical properties of cement i.e. initial and final setting times, Specific gravity, fineness, consistency has to be checked, before conducting the Mix-Design.

Coarse Aggregate: In the present study, locally available Coarse aggregate (Robo-Metal) of size 20mm was used. Its Specific gravity, Sieve analysis and Fineness Modulus have to be checked.

Fine Aggregate – Natural Sand: Locally available natural sand was used. Its Specific gravity, Sieve analysis and Fineness Modulus need to be checked. The Sieve analysis has to be conducted to classify the sand belonging to which Zone (I to IV), as per IS 383:1970. As sand grading becomes progressively finer, the grading changes from Zone-I to IV.

Fig.1 Fine Aggregate – Natural Sand

Fine Aggregate – Copper Slag: The Chemical analysis of Copper Slag has to be conducted, to check its Chemical composition. Simultaneously the tests to determine the Physical properties of Copper Slag i.e. Specific gravity, Sieve analysis and Fineness modulus has to be conducted.

Fig.2 Fine Aggregate – Natural Sand

Aggregate is the main constituent of concrete, occupying more than 70% of the concrete matrix. In many countries, there is a scarcity of natural aggregate that is suitable for construction, whereas in other countries the consumption of aggregate has increased in recent years, due to increases in the construction industry. In order to reduce depletion of natural aggregate due to construction, artificially manufactured aggregate and some industrial waste materials can be used as alternatives. Copper slag (CS), the glassy material, produced during 1matte smelting and copper conversion was previously considered waste and disposed as landfill.It has been estimated that for every ton of copper production about 2.2-3 tons of slag are generated. Slag containing < 0.8% copper are either discarded as waste or sold cheaply. The copper slag, the byproduct of the melting plant of Lac, copper slag can be used successfully as Portland cement substitute in the cement industry, sand substitute in concrete plant and in different ways. The treated spent copper slag can be recycled and put to good use as sand replacement in concrete. For structural usage, the use of copper slag as partial replacement of sand in concrete is allowed for up to 10% by mass.

IV. RESULTS

A. FOR ONE PLAIN CONCRETE BLOCK

Weight of cement=1.25kg
Water used=0.625lit Fine
Aggregate=1.948kg
Coarse aggregate=3.95kg

READINGS OF PLAIN CONCRETE BLOCK

Concrete Grade	No. of days	Load (KN)
M-25	7	410
M-25	14	590
M-25	28	690

Table.1: Load Bearing Capacity For Cubes

B. FOR REPLACED COPPER SLAG CONCRETE BLOCK:

DATA FOR CUBES REPLACED BY 20% COPPER SLAG

Weight of cement=1.25kg
Water used=0.625lit Fine
Aggregate=1.56kg Copper
Slag= 0.39kg Coarse
Aggregate=3.95kg

Concrete Grade	No. of days	Load (KN)
M-25	7	475
M-25	14	600
M-25	28	795

Table.2: Load Bearing Capacity For Cubes Replaced By 20% Copper Slag:

DATA FOR CUBES REPLACED BY 40% COPPER SLAG

Weight of cement=1.25kg
Water used=0.625lit Fine
Aggregate=1.17kg Copper
Slag= 0.78kg Coarse
Aggregate=3.95kg

Concrete Grade	No. of days	Load (KN)
M-25	7	695
M-25	14	890
M-25	28	1070

Table.3: Load Bearing Capacity For Cubes Replacement of 40% Copper Slag

DATA FOR CUBES REPLACED BY 50% COPPER SLAG

Weight of cement=1.25kg
Water used=0.625lit
Fine aggregate=0.974kg
Copper slag= 0.974kg
Coarse aggregate=3.95kg

Concrete grade	No. of days	Load(KN)
M25	7	710
M25	14	950
M25	28	1180

Table.4: Load Bearing Capacity For Cubes Replaced By50% Copper Slag:

DATA FOR CUBES REPLACED BY 60% COPPER SLAG

Weight of cement=1.25kg
Water used=0.625lit
Fine aggregate= 0.778kg
Copper slag= 1.17kg
Coarse aggregate=3.95kg

Concrete Grade	No. of days	Load (KN)
M-25	7	790
M-25	14	990
M-25	28	1250

Table.5: Load Bearing Capacity For Cubes Replaced By 60% Copper Slag:

RESULT

The load bearing capacity of replaced copper slag cubes gradually increasing as the percentage of copper slag in concrete is increased. By the graph shown below we can see that the strength of concrete cubes start increasing from 40% to 60% replacement. At 60%replacement the strength of concrete is maximum. As represented in the graph the strength is reducing as the percentage of copper slag increased more than 60%. Hence the 60% replacement of fine aggregate in concrete production can be done.

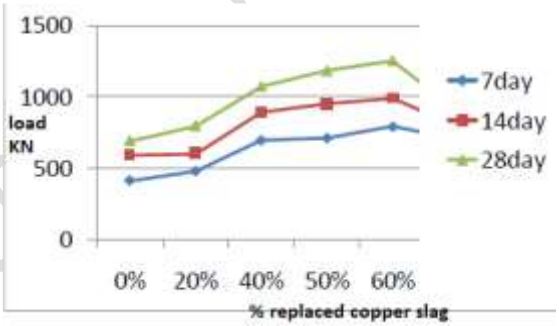

Fig.3: Graph Of Load Bearing Capacity Of Cubes

RESULTS OF COMPRESSIVE STRENGTH:

Average Compressive Strength and average Density test results of M-25 grade concrete using varying proportions (0 to 60%) of Copper Slag at 7-Day, 28-Day and 90-Days of curing.

Strength studies of M-25 grade concrete with varying proportions of copper slag

SLNo	Grade of Concrete	7-days strength (N/mm2)	14-days strength (N/mm2)	28-days strength (N/mm2)	Average Density
1	M-25	27.47	41.43	52.49	
2	M-25	26.52	40.05	49.51	2.479
3	M-25	27.44	41.16	51.63	
Average Strength		27.44	41.16	51.63	

RESULTS OF COMPRESSIVE STRENGTH OF CONCRETE USING 0% COPPER SLAG AT 7-DAYS, 14-DAYS AND 28-DAYS:

SLNo	Grade of Concrete	7-Days Strength (N/mm2)	14-Days Strength (N/mm2)	28-Days Strength (N/mm2	Average Density
1	M-25	30.56	46.09	53.91	2.54
2	M-25	31.51	45.29	52.44	
3	M-25	32.39	45.62	54.49	
Average Strength		31.49	45.67	53.61	

RESULTS OF COMPRESSIVE STRENGTH OF CONCRETE USING 20% OF COPPER SLAG AT 7-DAYS, 14-DAYS AND 28-DAYS:

SLNo	Grade of concrete	7-day strength (N/mm2)	14-days strength (N/mm2)	28-days strength (N/mm2)	Average Density
1	M-25	33.24	47.34	55.56	2.567
2	M-25	33.44	46.45	55.92	
3	M-25	31.2	48.58	55.04	
Average Strength		32.63	47.41	55.51	

RESULTS OF COMPRESSIVE STRENGTH OF CONCRETE USING 40% OF COPPER SLAG AT 7-DAYS, 14-DAYS AND 28-DAYS:

SLNo	Grade of concrete	7-days strength (N/mm2)	14-days strength (N/mm2)	28-days strength (N/mm2)	Average Density
1	M-25	22.29	44.32	49.91	2.596
2	M-25	29.85	47.28	50.49	
3	M-25	28.63	45.96	50.98	
Average Strength		29.26	45.85	50.46	

RESULTS OF COMPRESSIVE STRENGTH OF CONCRETE USING 60% OF COPPER SLAG AT 7-DAYS, 14-DAYS AND 28-DAYS:

%Replacement of sand with copper slag	M-25 Grade Concrete Mix		
	7-days	14-days	28-days
0%	27.44	41.16	51.63
10%	27.96	43.23	52.39
20%	31.49	45.67	53.61
40%	31.91	46.91	55.17
50%	32.63	47.41	55.51
60%	29.26	45.85	50.46

ABSTRACT STATEMENT ON COMPRESSIVE STRENGTH OF CONCRETE SPECIMENS (N/MM2):

%Replacement of sand with copper slag	Compressive strength at 7-days	Strength gained at 7-days	Compressive strength at 14-days	Strength gained at 14-days	Compressive strength at 28-days	Strength at 28-days
0%	27.44	100.0%	41.16	100.0%	51.63	100.0%
10%	27.96	101.9%	43.23	105.2%	52.39	101.5%
20%	31.49	114.8%	45.67	111.0%	53.61	103.8%
40%	31.91	116.3%	46.91	114.0%	55.17	106.9%
50%	32.63	118.9%	47.41	115.2%	55.51	107.5%
60%	29.26	103.6%	45.85	111.4%	50.46	97.7%

RESULTS OF SPLIT-TENSILE STRENGTH:

S.No	Grade of concrete	7-days strength (N/mm2)	14-days strength (N/mm2)	28-days strength (N/mm2)
1	M-25	2.409	2.762	3.19
2	M-25	2.513	2.967	3.54
3	M-25	2.147	3.042	3.29
Average Strength		2.236	2.924	3.34

RESULTS OF SPLIT TENSILE STRENGTH OF M-25 CONCRETE USING 0% COPPER SLAG AT 7-DAYS, 14-DAYS AND 28-DAYS:

S.No	Grade of concrete	7-days strength (N/mm2)	14-days strength (N/mm2)	28-days strength (N/mm2)
1	M-25	1.547	2.917	3.46
2	M-25	1.779	3.202	3.79
3	M-25	1.949	2.827	3.76
Average Strength		1.758	2.982	3.67

CONCLUSION

From the above result it can be concluded that we are going to use copper slag as an alternative of fine aggregate the cost of concrete production will be reduced and strength of 60% replaced copper slag concrete will be increased to twice of plain concrete strength. Based on the experimental investigations carried out, the following conclusions were drawn:

- The behavior of Copper Slag seems to be similar to River Sand, for its use as fine aggregate (partially or in blending) in Concrete mixes.
- Addition of Copper Slag (having higher Density) in Concrete increases the density, thereby the self-weight of Concrete, (by about 4.5% for 50% replacement).
- The results showed that the workability of Concrete increased substantially with increase of Copper Slag content in the concrete mixture due to the low water absorption, coarser (in nature than sand) and glassy surface of Copper slag, thereby the Strength properties also improved.
- The Compressive Strength of Concrete is comparable to the control mix up to 40% of Copper Slag substitution, but they decrease with a further increase in Copper Slag contents (due to the increase of free water content in the mix).
- The early Compressive Strength of Concrete was not adversely affected by Copper Slag addition up to the proportion of 40%.
- Compressive Strength and Flexural Strength of Copper Slag admixture Concrete, increased due to high toughness of Copper Slag.
- Replacement of Copper Slag as fine aggregate in concrete mixes, reduces the cost of concrete production.

- The results showed that copper slag used in concrete, strength increases 20% to 60% then after it starts decreases.

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